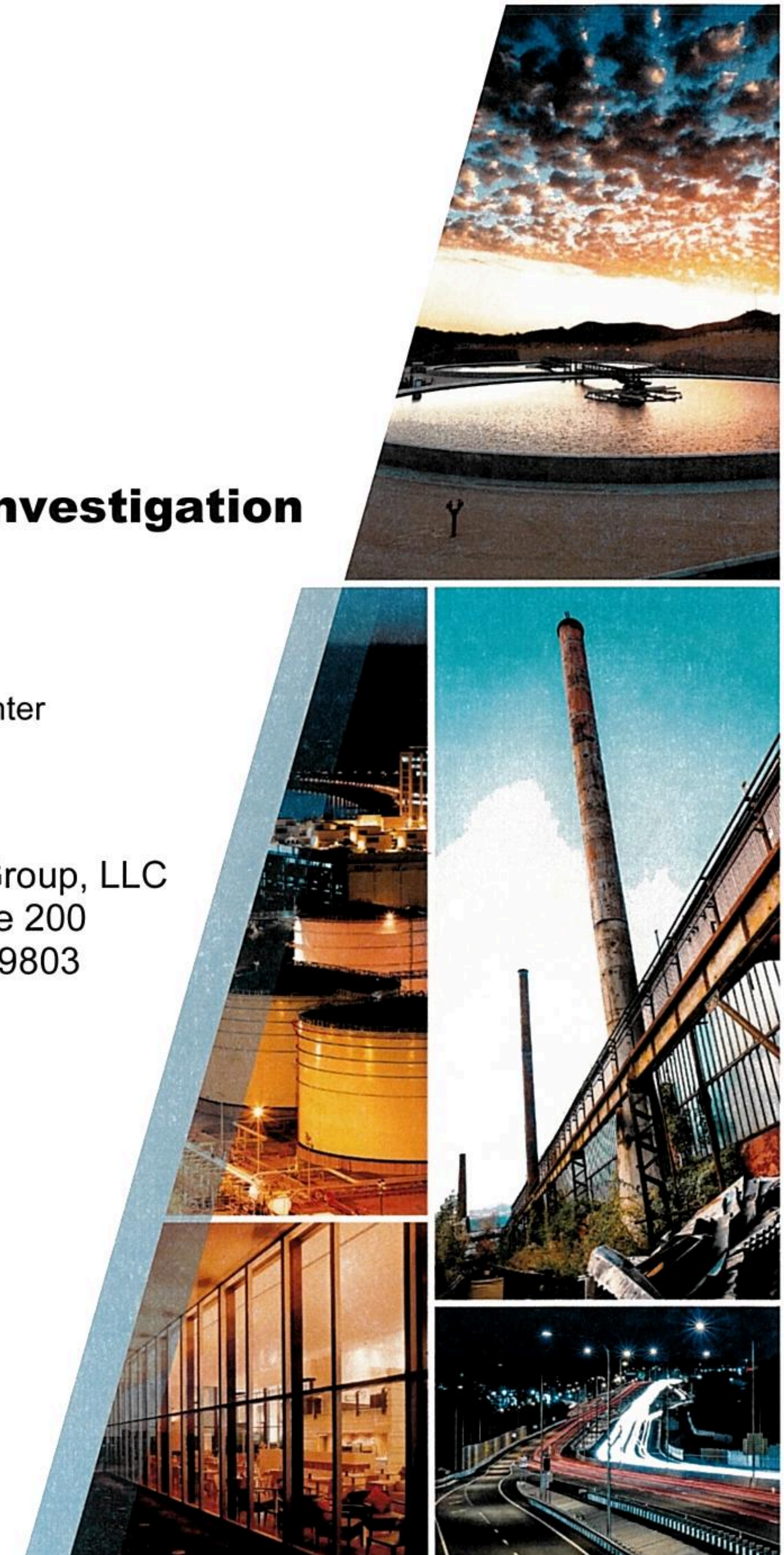
RCRA Facility Investigation Report

AOI 7
Former Ethylene Complex
Marcus Hook Industrial Center
Claymont, Delaware



Evergreen Resources Group, LLC
2 Righter Parkway, Suite 200
Wilmington, Delaware 19803

GHD | 410 Eagleview Boulevard Suite 110 Exton Pennsylvania 19341 | 11102641 | 7 | Report No 3 | June 7 2017, Revised April 8 2019

Table of Content

Table of Contents

Table of Contents

Table of Contents

Figure Index

Figure Index

Table Index

Table Index

Appendix Index

1. Introduction

This Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report has been prepared on behalf of the Evergreen Resources Group (Evergreen) to present the findings of the RFI for Area of Interest (AOI) 7 (referred to as AOI 7) - Former Ethylene Complex at the Marcus Hook Industrial Complex (MHIC). The MHIC is located in southeastern Pennsylvania and northern Delaware on the Delaware River (Figure 1.1). The following subsections describe the project background and strategy. Subsequent sections present descriptions of the facility, methods of investigation, investigation results, and data evaluation along with recommendations for additional corrective action activities.

Sunoco, Inc. (R&M) entered the facility into Corrective Action with the United States Environmental Protection Agency (USEPA) in order to satisfy Corrective Action obligations under RCRA. Evergreen assumed any liabilities of Sunoco arising from the environmental condition at the property existing or occurring prior to December 30, 2013. For the purpose of this report, the term property or facility refers to MHIC land previously owned by Sunoco, Inc. (R&M). As part of the sale of the property to Sunoco Partners Marketing & Terminals, L.P. (SPMT), SPMT agreed to be responsible for liabilities which are caused by or arise out of the ownership or operation of the property after April 1, 2013. SPMT is currently operating under a RCRA Part B permit with Corrective Action obligations to the USEPA.

1.1 Regulatory History/Overview

Sunoco, Inc. (R&M) submitted a Work Plan for a Site Wide Approach (Site Wide Work Plan) to the Pennsylvania Department of Environmental Protection (PADEP) and the USEPA on December 19, 2011 to serve as a roadmap to navigate the facility through the site characterization and remediation process to achieve site closure (Langan, 2011). As part of this Work Plan, Sunoco, Inc. (R&M) originally divided the facility into seven AOIs based on operational areas and risk-based factors including product types, potential exposure pathways, receptors, known light non-aqueous phase liquid (LNAPL) quantities, and historical information. The boundaries of AOIs 5 and 7 were revised in 2012 to be reflective of state lines. AOI 8 was added in 2013. The boundaries of the AOIs at the facility are presented on Figure 1.2.

On January 30, 2012, Sunoco, Inc. (R&M) submitted a Current Conditions Report and Comprehensive Remedial Plan (CCR) for the facility (Langan, 2012a). The CCR served as an initial assessment of the facility and drew its information from a variety of sources including historical reports, employee accounts, regulatory history, and on-site preliminary observations. The CCR presented a detailed Conceptual Site Model (CSM) based on available historic information and review of historic environmental reports. The CCR also included a discussion of Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) listed in the 1991 Phase II RCRA Facility Assessment Report (1991 Phase II RFA) (A.T. Kearney, 1991).

Evergreen and USEPA are working under a Corrective Action Framework (CAF) under the RCRA First program. The CAF is provided in Appendix A. The CAF lays out provisions for RCRA Corrective Action work designed to meet USEPA's RCRA 2020 goals.

Evergreen submitted a work plan for the RFI to the USEPA in May 2015. This work plan was reviewed with the USEPA on June 22, 2015. The preliminary results of the first phase of the RFI and the scope of the second phase of the RFI were presented to the USEPA on April 13, 2016.

2. Site Description and Background

The following subsections present a description of the facility, its historical industrial uses, the history of environmental programs and investigations and the current use of the facility. Section 2.3.2 also provides a discussion on site uses and environmental investigations on the adjacent Delaware Valley Works (DVW) property. For the purpose of this report, GHD has attempted to use the term facility or property to be consistent with the MHIC as defined above; however, we have used the term 'site' in a manner consistent with environmental investigations (i.e., on-site sampling, site-specific goals).

2.1 General Description

The MHIC is located on the north bank of the Delaware River (River) in the Borough of Marcus Hook, Delaware County, Pennsylvania, with portions of the facility in Lower Chichester Township, Pennsylvania and Claymont, New Castle County, Delaware (see Figure 2.1). The facility frontage extends approximately 4,800 feet along the northern banks of the Delaware River. The facility, which is located on industrial property, covers approximately 585 acres of land with access restricted by fencing and security measures.

Current operation of the facility (24 hours per day) includes the processing and storage of light hydrocarbon products plus support facilities. Support facilities include a flare, a wastewater treatment area, boilers, air compressors, loading and unloading facilities, and the production of racing gasoline. Sunoco Partners is retrofitting the facility with new facilities to process, store, chill, and distribute propane and ethane. A portion of the facility known as Phillips Island (AOI 5) is occupied by a combined-cycle, co-generation, and natural gas-fired power plant owned and operated by a subsidiary of NextEra Energy Resources. Braskem, Inc. leases the polypropylene plant (AOI 8). The area surrounding the facility is characterized by a mixture of residential, commercial, recreational, active industrial, and vacant industrial properties.

AOI 7 is located in Delaware and consists of approximately 50 acres of land bounded on the southeast by the Delaware River, the southwest by a property boundary with DVW, also referred to as General Chemical and Honeywell and by the Pennsylvania-Delaware state line/AOI 5 on the northeast. Middle Creek runs east-west then turns and runs north-south through AOI 7.

For the purposes of description in this report, directions will be according to plant coordinates, with the River described as the southern limit, the boundary with DVW property as the west limit and the state line/AOI 5 boundary as the eastern limit of AOI 7.

2.2 Historical Use

2.2.1 Marcus Hook Industrial Complex

The facility has a long history of petroleum transportation, storage, and refining of fuels and petrochemicals. Operations began in 1902, and the facility was owned and operated by Sunoco since its inception as Sun Oil in 1901. On December 1, 2011, Sunoco, Inc. (R&M) announced the indefinite idling of the main processing units at the facility due to deteriorating refining market conditions. On October 5, 2012, Energy Transfer Partners, L.P. (ETP) and Sunoco, Inc. (R&M) announced the merger of the facility into SPMT as a wholly owned subsidiary of ETP. The Marcus Hook Property was transferred to SPMT on April 1, 2013. SPMT transitioned the former Marcus Hook Refinery into an operation referred to as the SPMT Marcus Hook Industrial Complex.

2.2.2 AOI 7 Ethylene Complex

AOI 7 was generally undeveloped until the late 1950s. Prior to development, AOI 7 generally consisted of a low lying floodplain and marsh area. The surface of AOI 7 was significantly modified by filling and Middle Creek was relocated several times during development (see Section 2.2.1.2) between 1930s to late 1950s. Appendix B presents historical aerial photographs of AOI 7.

In 1958 a joint venture was formed between the Sun Company and the Olin Chemical Company that was named SunOlin Chemical Company (SunOlin). SunOlin purchased 33.5 acres of property in 1958 and constructed and operated a urea manufacturing process using ammonia feed from the Sun refinery and carbon dioxide from a Kellog Steam Methane Reformer, which also produced carbon monoxide and merchant hydrogen. In 1961 SunOlin built and began operation of the Ethylene and Ethylene Oxide units to extract ethylene from waste gas transported by an overhead pipeline from the refinery. The Ethylene and Ethylene Oxide units came to occupy the majority of AOI 7, including all of the area south and east of Middle Creek to the Delaware River and the state line. The operation of the urea plant ceased in 1973. Sun acquired Olin's interest in SunOlin in 1987 and the units became integrated into the refinery. The Ethylene and Ethylene Oxide units ceased operation in 2010.

Following shutdown of the Ethylene and Ethylene oxide units, industrial activity continued at a glycol unit in AOI 7. Rail lines in AOI 7 continued to be used for staging of train cars. The former industrial units at AOI 7 were decommissioned and are in the process of being demolished. The planned use for AOI 7 is for natural gas liquids finishing, storage and shipment operations.

2.3 Environmental Setting

The following subsections present information on the environmental setting of the area local to the MHIC facility, the MHIC facility itself, and specific information relative to the setting of AOI 7.

2.3.1 Topography and Hydrology

2.3.1.1 Current Topography and Hydrology

Light Detection and Ranging (LiDAR) data obtained from the USGS (USGS, 2010) indicates that present-day topography is relatively flat across the facility, rising gently to the north from low elevations of approximately 6 feet at certain locations along the bank of the Delaware River to approximately 60 feet along Ridge Road [referenced to the North American Vertical Datum of 1988 (NAD 88). Just north of the facility, steeper topography is apparent. Storm water sheet flow follows topography and generally flows across the property towards the Delaware River. The facility's combined wastewater/stormwater drainage system collects process wastewater and stormwater from all process areas of the facility except for the east side of the facility. In this area, storm runoff is sent to an 84-inch pipe that combines with runoff from the surrounding community and discharges at National Pollutant Discharge Elimination System (NPDES) permitted Outfall 020. All storm lines, except those draining to Outfall 020, drain first to Impoundment Tank T-101-K, then to the separator/wastewater pretreatment plant, and then finally to the DELCORA Publicly Owned Treatment Works (POTW).

The Ethylene Complex (AOI 7), located in the southwest corner of the facility, has a segregated sewer system. One system collects process wastewater and process area stormwater, and a second system collects other non-process area "clean" stormwater. Non-process area stormwater is discharged, via several outfalls, directly to Middle Creek and the Delaware River and is regulated under a Delaware NPDES Permit, No. DE0050288. Process wastewater from the former Ethylene Complex and process related stormwater is routed to the facility's surge tanks TK-130 and TK-131, where it receives treatment similar to that provided for other facility waste streams.

The highly modified and channelized Middle Creek and Walker's Run served as conveyance for containment and transport of both local stormwater and process wastewater until the early 1990s when the majority of Middle Creek became contained in a conveyance system. Surface water now mostly travels through an open concrete channel, roughly following the former Walker's Run and Middle Creek beds, and process waste is conveyed within enclosed piping inside of the concrete channel. The stormwater conveyance terminates just east of Blueball Avenue at a sump (Brown and Root, 1993), and then is transferred to the publicly owned treatment facility at the Delaware County Regional Authority (DELCORA). Currently, a remnant of Middle Creek exists to the southwest of the concrete dam located in the vicinity of the Middle Creek Interceptor Trench Recovery System (AOI 5) and connects to the Delaware River at the southwestern corner of the facility in Delaware (AOI 7).

2.3.1.2 Historical Topography and Drainage

Topography in AOI 7 was naturally low lying coastal plain prior to development in the early 20th century. Figure 2.2 shows the locations of historic streams and marshes circa 1898 within the facility. In this figure, Walker's Run, a former perennial stream, daylights as a spring at the slope located just to the north of Ridge Road. This northeast/southwest trending portion of Walker's Run is what would later be referred to as "Middle Creek". An additional stream (called Bear Creek) is also noted to have existed to the west of current Blueball Road and merged with Walker's Run near its confluence with the Delaware River at a point near the state line as shown on Figure 2.3.

The course of these surface water features was altered throughout the development of the former refinery, which involved channelization and straightening of the creek's path and movement of its mouth to the west within AOI 7. Figure 2.3 depicts the course of the natural streams in 1898 and the relocated channels described below. An aerial photograph (Figure 2.4A) of the facility in 1937 shows a relocation of the last 400 feet of Middle Creek approximately 160 feet to the west. An aerial photograph of the facility in 1953 (Figure 2.4A) shows a relocation of the downstream portion of Middle Creek approximately 500 feet further west, to discharge near the current intersection of Third and C Streets. The final rerouting of Middle Creek is depicted in an aerial photograph from 1958 (Figure 2.4B) and shows a 90 degree turn to the southeast to a new discharge point at the Delaware River near the property boundary. The remaining open section of Middle Creek drains the area southwest of the dam through the bend and connects to the Delaware River at the southwestern corner of the facility in Delaware (AOI 7). A sheet pile bulkhead exists along the facility boundary with the Delaware River.

Approximately 60 percent of the area of AOI 7 was originally low lying, being either under the Delaware River (and later reclaimed) or in a marsh area adjacent to the natural Middle Creek. These low lying areas were reclaimed by the placement of fill to raise the ground surface above the Delaware River and provide a stable base for subsequent development. Figure 2.3 shows changes to the river bank based on historical aerial photographs that are shown on Figures 2.4A and 2.4B. The progress of this fill placement is most noticeable from 1953 through 1965. Between 1953 and 1958 an area 250 feet wide against the western property line was filled out approximately 500 feet into the river to the current bulkhead line. Between 1958 when the property south of Middle Creek was sold to SunOlin and 1962 after construction of the Ethylene and Ethylene Oxide units, the remainder of the riverfront margin of AOI 7 was filled to the current bulkhead line. Much of this filling occurred in 1960 according to the Ethylene Complex History of Landfilling (Palese & Brenner, 1989). The materials were placed to bring the elevation of the area to 15 feet above mean sea level (AMSL) and then eventually to the current elevation of approximately 19 feet AMSL in the southern portion of AOI 7.

As seen on Figure 2.4A, industrial activity at the DVW was ongoing to the west of AOI 7 prior to the filling and development of the Ethylene Complex area, which began in the late 1950s. Filling activity at DVW was noticeable adjacent to the AOI 7 boundary as early as 1937, and bermed areas that appear to have received siltation are apparent in the 1950s. A large pond and an apparent disposal pile appear just west of the property boundary in the 1965 aerial photograph (Figure 2.4B). Tonality in the 1937 aerial photograph (Figure 2.4A) indicates the presence of mud flats and unconsolidated sediment material spanning the riverfront from DVW east to AOI 7. This pattern indicates the movement of materials from the adjacent DVW property to locations within the current AOI 7 boundary.

According to the account of the Ethylene Complex History of Landfilling (Palese & Brenner, 1989), the fill materials placed in AOI 7 included building debris (such as concrete slabs, bricks and lumber) covered by refinery waste (a mixture of spent clay catalyst and natural earth, silt or clay with sand and some gravel). Following the sale of property to SunOlin, a more deliberate campaign of fill placement occurred between 1958 and 1962, as noted above. This fill consisted of blends of spent catalysts with river silts in the following combinations:

- Blend A: one part river silt mixed with two parts spent clay catalyst from oil production in the 14-3 Plant.
- Blend B: one part river silt mixed with one part natural clay and one part spent catalyst from wax production in the 14-3 Plant.

The fill material was observed to move as it was placed in the saturated area behind the berm as noted in the Ethylene Complex History of Landfilling (Palese & Brenner, 1989). From these descriptions, it is evident that the filling activities created a sufficient disturbance in the fill to have mixed the fill with historical sediments during filling of the area.

2.3.2 Geology

2.3.2.1 Local Geology

The facility is located on the up-dip edge of the Coastal Plain Physiographic Province near its contact with the Piedmont Physiographic Province. The Coastal Plain is characterized by relatively low topography and is underlain by unconsolidated deposits of mud, sand, and gravel-sized materials. Within the Coastal Plain, sedimentary deposits generally decrease in thickness and "pinch out" against crystalline bedrock of the Piedmont along a transition zone referred to as the "Fall Line", which is located along the northern boundary of the facility (Figure 2.5). The Coastal Plain consists of a seaward-thickening, wedge-shaped sequence of sedimentary deposits that accumulated in a variety of marine and non-marine environments. Defined geologic units/formations of the Coastal Plain outcrop and subcrop the facility and generally strike northeast/southwest, dip to the southeast, and overlie a deepening bedrock surface.

According to published geologic maps of the facility area, sedimentary deposits of the Coastal Plain near the facility range in age from Quaternary to Holocene (Figure 2.5). In Pennsylvania, the Coastal Plain sediments are identified as belonging to the Quaternary Trenton gravel, which is generally present between sea level and 40 feet AMSL (along a river terrace) with local thicknesses that are commonly less than 20 feet (Balmer & Davis, 1996). The Trenton gravel is discontinuous in aerial extent, variable in vertical thickness and range of elevation, and primarily consists of gravelly sand interstratified with semi-consolidated sand (limonite-cemented) and clay-silt beds (Owens & Minard, 1979). The Trenton gravel is commonly gray or pale reddish brown in color. In Delaware, Quaternary deposits are identified as undifferentiated Delaware Bay Group (upper Pleistocene) consisting primarily of sandy alluvium but with secondary lithologies including silty clay, peat, and sandy gravel in thicknesses up to 20 feet (Ramsey, 2005).

According to the Bedrock Geology Map of the Piedmont of Delaware and Adjacent Pennsylvania (Plank, Schenck & Srogi, 2000), bedrock beneath the facility is of the Wilmington Complex. The Wilmington Complex consists of metamorphosed igneous rocks including meta-volcanic units, meta-plutonic units, and un-deformed plutons. More recently in 2008, Bosbyshell published an updated bedrock geologic map that included mapping of the facility area (Figure 2.5). Although bedrock was not mapped beneath the Coastal Plain, that map continues to indicate that the Ardentown Granitic Suite is present beneath portions of the facility.

2.3.2.2 Facility Geology

Although the subsurface conditions above bedrock at the facility are locally heterogeneous, the geologic framework underlying the facility can be grouped into three general units. The uppermost unit is anthropogenic fill, which generally covers the entire surface of the facility to varying depths. Underlying the fill is recent alluvium consisting primarily of silty clay which may have been deposited in estuarine environments of the Delaware River or a tributary, such as Middle Creek. The third unit includes unconsolidated sands and gravels with silt and clay, which fits published descriptions of the Trenton gravel (or adjacent Delaware Bay Group in Delaware).

Fill has been reported to be present underlying the entire facility at variable extent and thickness ranging from approximately 1 to 25 feet; however, fill is thicker in areas where reclamation extended into the Delaware River, such as in AOI 7. The fill composition varies, but generally is composed of one or more of the following: silt, sand, gravel, clay, wood fragments, cinders, apparent dredged material, sludge, spent clay, and other construction/demolition or refinery materials. Portions of the facility that extend beyond the historic Delaware River shoreline of 1937 were generated by filling of the Delaware River margin with various refinery-generated materials. This area generally correlates to that shown as Fill (f) on Figure 2.5 (Ramsey, 2005).

Underlying the fill unit are silty clay sediments, hereafter referred to as the silty clay layer. The silty clay layer within the facility consists of micaceous, greenish-gray silty clay with minor roots, wood, peat, and other vegetative material, but can vary to include interbedded fine-grained sands, silty sands, clayey silts, and gravels. The light to dark gray silty clay is generally soft but can become stiff with depth or where sandy. The lithology of the silty clay layer is consistent with what Owens & Minard (1979) describe as Delaware Bay estuarine deposits, an organic-rich estuarine facies consisting of dark colored clayey silts interbedded with fine to very fine sand. The silty clay layer is present beneath most of the facility and thickens towards the east and the historical shoreline of 1937. Beneath the facility, the silty clay layer ranges in thickness from approximately 5 to 20 feet.

Apparent Trenton gravel deposits underlie the silty clay layer and unconformably overlie bedrock at the facility. The Trenton gravel generally ranges in thickness from approximately 2 to 10 feet. The Trenton gravel consists of fine to coarse-grained sand, gravel, sandy silt, and clayey sand. The sand and gravel unit is present throughout much of the facility; however, its thickest deposits vary laterally. The sands and gravels commonly coarsen with increasing depth. Cobbles may be present atop bedrock in some areas of the facility, generally along the shoreline of the Delaware River.

Bedrock at the facility has been identified through test boring advancement. Where encountered, a saprolite layer is common that contains a visible rock fabric consistent with published descriptions of Ardentown Granitic Suite crystalline bedrock. Along the northern facility boundary, bedrock was identified near surface beneath a veneer of a few feet of fill. The bedrock surface slopes south and deepens towards the Delaware River. The elevation of the top of crystalline bedrock (including saprolite) at the facility ranges from approximately 30 feet to deeper than -50 feet NAVD 88.

2.3.2.3 AOI 7 Geology

Historic geotechnical borings from 1957 to 1961 indicate that the thickness of fill in the Ethylene Complex to be approximately 10 feet north of the 1937 shore line (the 1937 shore line is shown on Figure 2.4A) and 20 feet or more between the 1937 shore line and the current river bulkhead. Borings completed as part of the RFI confirmed fill thickness north of Middle Creek to be 12 to 15 feet and fill thickness along the current river bulkhead to be 25 to 30 feet, Bedrock depth was noted to range from 25 feet in the northern end of AOI 7 to 65 feet below grade at the current river bulkhead (Palese & Brennan, 1989). None of the RFI borings were completed to bedrock.

The installation of monitoring wells and soil borings in AOI 7 during the RFI occurred primarily in fill materials. Stratigraphy logs (Appendix F) document the presence of sandy silts and silty clays throughout the majority of the investigated interval. The bottom of some of the RFI borings intersected native dark gray silty clays which correlate with the silty clay layer described in Section 2.3.2.2 at depths of 25 to 30 feet below grade.

2.3.3 Hydrogeology

2.3.3.1 Facility Hydrogeology

In southeastern Pennsylvania, unconsolidated sands and gravels of the Coastal Plain and fractured crystalline bedrock of the Piedmont can function as aquifers where saturated and sufficiently permeable. Crystalline bedrock, particularly igneous and high-grade metamorphic rock types such as those associated with the Wilmington Complex, generally has low porosity with little, if any, secondary porosity/permeability yielding poor water-producing capabilities. Near the facility, these rocks have been described to yield too little water for industrial or public water supply (Balmer & Davis, 1996) and have a median well yield of less than 10 gallons per minute (gpm) (Bosbyshell, 2008). Where unconsolidated Coastal Plain sediments are present at the land surface, these rock types have been further described to "serve chiefly as a lower confining layer to retard movement of water of the overlying aquifers" (Greenman, Rima, Lockwood, & Meisler, 1961). Balmer & Davis (1996) provide a median yield of 50 gpm for wells screened in the Trenton gravel in Delaware County. However, transmissivities may be limited due to that deposit's small saturated thickness and local-scale heterogeneity. Recent alluvial deposits, including the Delaware River Estuarine silty clay and the Trenton gravel, are not expected to represent a significant potable water source in eastern Delaware County based on potential saline/brackish water impacts from the Delaware River (Balmer & Davis, 1996). The facility and the surrounding areas are served by public water supply and river water intakes.

At the facility, monitoring well data indicates that groundwater can occur in areas of fill, the silty clay layer, and/or Trenton gravel units at depths ranging from approximately 1 to 20 feet (ft.) below ground surface (bgs). Groundwater generally occurs within these strata under unconfined conditions as one continuous water-bearing unit (e.g., water-table aquifer), and groundwater elevations generally decrease towards the shoreline of the Delaware River. However, perched groundwater can occur within the fill layer where the fill is present atop the silty clay layer, and where the top of the silty clay layer is above the regional zone of saturation.

Presently, a network of approximately 550 monitoring and 120 recovery wells is used to monitor groundwater quality; understand pattern(s) of groundwater flow; and recover/remediate groundwater within the facility (Figure 2.6). To evaluate recent, facility-wide patterns of groundwater flow, groundwater elevation contour maps were created from annual synoptic well gauging events. Figure 2.6 shows the October 2016 facility wide groundwater elevations. Based on the groundwater contours presented, the average hydraulic gradient across the facility is approximately 0.007 to 0.008 feet/foot (ft/ft), and facility-wide groundwater flow is generally towards the southeast. However, some variability in groundwater flow direction is noted. Groundwater flow appears to be affected by Middle Creek in AOI 7, where there is potential for groundwater discharge to surface water. Groundwater elevations are also locally depressed in areas of active groundwater recovery and remediation systems. Groundwater elevations along the tidal Delaware River appear to be influenced by semidiurnal tides, where maximum groundwater fluctuations of approximately 1 to

2.7 feet immediately adjacent to the Delaware River and 0.1 to 0.15 feet approximately 300 feet inland were recently observed in monitoring wells during a tidal study conducted as discussed in Section 4.2.1.1. Some localized groundwater mounding is apparent adjacent to the Delaware River possibly due to backup of groundwater behind the river bulkhead.

2.3.3.2 AOI 7 Hydrogeology

Groundwater elevations in AOI 7 range from -0.5 feet to 12.8 feet AMSL and range in depth from 4.4 to 14 feet below grade. The groundwater interface in AOI 7 resides in fill material which is typically present 10 to 25 feet bgs, although underlying natural silty clay alluvium and gravel units are also saturated, where present.

Groundwater generally flows southeast toward the Delaware River or locally towards Middle Creek. Groundwater is locally influenced by pumping associated with fluids recovery by the Middle Creek remediation system, as shown on Figure 2.6. In the downstream section of the creek, groundwater flow appears to be less influenced by Middle Creek due to the proximity of this area to the Delaware River. Groundwater within close proximity to the Delaware River is influenced by the existing bulkhead and the tidally-influenced river stage. The tidal study results (Section 4.2.1.1) showed some wells along the river front where the bulkhead was present did not respond to tidal changes as much as others. As noted in the results of the tidal study (Section 4.2.1.1) however, the effects of tidal stage in the Delaware River on groundwater elevations are significant along the river bank, but are diminished at a distance of 250 feet from the river (e.g., as seen in MW-533). The observed area where the tidal influences are diminished correlates with the 1937 shoreline.

Groundwater elevation data collected during the RFI agree with those collected as part of the annual synoptic well gauging events. Figure 2.6 shows the groundwater contours generated based on the groundwater elevation data collected in October 2016 during the RFI. Based on the facility-wide groundwater contours (Figure 2.6) and the AOI 7 groundwater contours (Figure 4.11), the average hydraulic gradient in AOI 7 towards the Delaware River is approximately 0.008 to 0.05 feet per foot (ft/ft), and flow towards Middle Creek, in areas not influenced by remedial pumping, is 0.008 to 0.05 ft/ft.

2.3.3.3 LNAPL

As shown on Figure 2.7, LNAPL exists in 11 monitoring wells in AOI 7 with apparent thickness ranging between approximately <0.01 and 8.21 feet. Data from 2015 and 2016 indicate that most of the monitoring wells where LNAPL was observed in the vicinity of operating recovery systems have very thin accumulations of less than 0.05 feet of LNAPL, including the wells at the Middle Creek Hydraulic Control System and those in the western portion of the Phillips Island Control system. Two localized areas LNAPL detections had trace (<0.01 at MW-47) or near trace amounts (0.02 at MW-558) of LNAPL. Monitoring wells in the center of the Ethylene Complex had product thicknesses greater than one foot (MW-562, MW-534L, and MW-55). The only wells installed during the RFI where LNAPL was detected were MW-534 and MW-562.

2.3.3.4 Ecological Resources

The surface of AOI 7 is covered with gravel, industrial structures and paved surfaces. Consequently there are generally no areas of habitat for ecological receptors. Limited terrestrial habitat is present as an area of weedy herbaceous cover of approximately 3/4 of an acre between rail siding and freight rail lines along the western property boundary with DVW. A very narrow fringe of scrub or shrub cover is also present along the Delaware River bank. The key ecological feature of AOI 7 is Middle Creek, a stormwater ditch that drains to the Delaware River at the southwestern corner of AOI 7. Middle Creek is tidally influenced along its entire length of 2,500 feet. Middle Creek is a roughly trapezoidal, man-made drainage feature with a substrate consisting of 18 to 24 inches of unconsolidated sediment (predominately silt) underlain by variable sized gravel and rip-rap.

The Screening Level Ecological Risk Assessment (SLERA) provided in Appendix N provides additional description of the habitat cover and potential ecological receptors in AOI 7.

2.3.3.5 Current Use and Future Use

The Marcus Hook Industrial Complex includes terminalling and storage facilities, with a capacity of approximately 3 million barrels of natural gas liquid (NGL) storage capacity. The facility can receives NGLs via marine vessel, pipeline, truck and rail, and can deliver via marine vessel, pipeline and truck. In addition to providing NGLs storage and terminalling services to both affiliates and third-party customers, the Marcus Hook Industrial Complex currently serves as an off-take outlet for the Mariner East 1 pipeline, and will provide similar off-take capabilities for the Mariner East 2 pipeline when it commences operations.

Currently the facility is undergoing major redevelopment in association with the Mariner East projects and other infrastructure changes. Much of the infrastructure associated with the former refining operations has been decommissioned and demolished. SPMT's future plans for the facility include natural gas liquids finishing, storage and shipment operations.

2.4 Environmental History

2.4.1 AOI 7 Marcus Hook Industrial Complex

Several environmental investigations were completed in AOI 7 prior to the RFI. The majority of these investigations focused on Phillips Island located to the east of AOI 7 in AOI 5 but collected data within AOI 7 that was used to developed the scope of the RFI. These investigations included:

- Environmental Resources Management. (1990). Report on Subsurface Investigation of Closed Waste Units at the Sun Marcus Hook Refinery, Pennsylvania This report addressed five units in and associated with the Marcus Hook Refinery. Two units within the current AOI 7 boundaries included SWMU 23/24 Former Sludge Basin/Former Decant Basin and SWMU 27 Phillips Island.
- A.T. Kearney, Inc. (1991). Phase II Final Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) for the Sun Refining and Marketing Company Marcus Hook Refinery, Marcus Hook, Pennsylvania. This report focused on the SWMUs in AOI 7. These SWMUs included SWMU 23, 24, 27, and 96.

- Groundwater and Environmental Services (GES). (1995). Ethylene Complex & Phillips Island, Perimeter Groundwater Assessment (and Addendum), Area 9. This report collected data to assess groundwater conditions in the vicinity of Phillips Island.
- GES (1999). Ethylene Complex & Phillips Island, Remedial Action Plan Area 9. This report addressed the recovery of LNAPL from wells near the Delaware River by installation of dedicated recovery and periodic vacuum recovery.
- Dames & Moore. (1999). Phase I Environmental Site Assessment, Phillips Island, Sunoco Inc. (R&M).
- URS Corporation. (2005). Final Report Phillips Island, Marcus Hook Refinery, Marcus Hook, Pennsylvania. This report detailed the investigation and remediation completed in relation to Phillips Island in accordance with the Pennsylvania Act 2 Program.

The facility Environmental History is further described in the Current Conditions Report (Appendix C).

2.4.1.1 AOI 7 SWMUs and Former SWMUs

AOI 7 has two SWMUs, shown on Figure 2.8, that were identified in the RFA issued by A.T. Kearney in 1991. The SWMUS are shown on Figure 2.8. Each of these SWMUs is located in both AOI 7 and the adjacent AOI 5 to the east. Prior investigations and remedial action have been completed on each of these SWMUs. Remedial activities have included treatment of sludge materials at the Former Sludge Basin/Former Decant Basin (SWMU 23/24), and cover placement and seepage controls (with LNAPL recovery) at Phillips Island (SWMU 27). Additional corrective action was performed on the enclosure of the Middle Creek Drainage System (formerly SWMU 96) and the recovery of LNAPL adjacent to Middle Creek.

Old Sludge Basin SWMU 23 and Old Decant Basin SWMU 24

Two basins located to the north of Middle Creek have been identified as SWMU 23 Old Sludge Basin and SWMU 24 Old Decant Basin. These former units are situated in the southwestern section of the facility, see Figure 2.8. The two basins are adjacent to one another, with the Old Sludge Basin on the west side and the Old Decant Basin on the east as shown on Figure 2.8. The combined dimensions of the units are reported as being 280 feet by 220 feet, covering approximately 1.4 acres (A.T. Kearney, 1991).

The former units were unlined surface impoundments used for the disposal of American Petroleum Institute (API) separator sludges and leaded tank bottoms. The units operated between the 1950s and the late 1970s. There were no releases associated with these units during their active life. According to the facility's 1980 Notification of Hazardous Waste Site(s), the two units together contain up to 490,000 cubic feet of waste treated with fly ash. In addition to fly ash treatment, other treatment chemicals have been applied to stabilize these materials as indicated by the purple color of the materials in SWMU 23/24.

Phillips Island SWMU 27

Phillips Island has been identified as SWMU 27. The majority of it exists in AOI 5, as shown on Figure 2.8, but a portion of it extends into the southeast corner of AOI 7. Phillips Island is an expansion area that was filled between the 1930s and the 1970s. The area consists of approximately 27 acres bounded on the southeast by the Delaware River. The unit received waste from the 1950s to the late 1970s, and ash in approximately 1985 to 1986.

Sunoco performed a site characterization, remedial investigation and risk assessment and developed a cleanup plan for Phillips Island and was granted a Release of Liability under Act 2 for this portion of the facility. Initial Act 2 results were reported in Act 2 Combined Report- Rev. 1 July 14, 2000. DEP approved the report on August 16, 2000. Remedial components of the Act 2 closure included installation of vapor intrusion mitigation systems, recovery wells and paving. The surface of Phillips Island was covered with asphalt and clean gravel as a barrier to direct contact and infiltration by storm water. The asphalt surface was graded to promote storm water runoff quality. Remedial action also included the containment of seepage areas along the river by the installation of sheet pile barriers and recovery wells behind the barrier to collect LNAPL. A sheet pile barrier was extended along the western river bank. The completion of remedial action was reported in Final Report Phillips Island Marcus Hook Refinery. URS Corporation September 2005. Act 2 ID 1-23-825-28219. The enhanced LNAPL recovery system was started in March 2004 (URS, 2005) and is still in operation. Remedial measures in AOI 7 as part of SWMU 27 include surface cover and recovery wells along the Delaware River, including OW-1 through OW-8.

Sunoco and Florida Power and Light constructed a co-generation station on a portion of Phillips Island in 2004 (Langan, 2012).

Middle Creek Drainage System

The Middle Creek Drainage System (formerly SWMU 96) was used as a waste-water conveyance for the facility. This open and unlined drainage system was closed between 1993 and 1995 through the implementation of the Middle Creek Abatement Project outlined in the Closure Plan and Post-Closure Plan (Brown & Root, 1993). The closure of the unit was approved by PADEP in 1995 and the unit is subject to post-closure requirements under that approved plan that includes inspection, maintenance, and groundwater monitoring. The closure work was performed outside of AOI 7 but extended to a point near the AOI 5/AOI 7 boundary. At that time, the sediments of the existing channel and associated pH Basin were stabilized and closed in place under a cap system consisting of a low permeability layer, a drainage layer and a geotextile layer. The surface over the closed basin area was covered in concrete and shotcrete. A reinforced concrete drainage channel was constructed along the channel axis to convey stormwater to storage and treatment. A pipe was installed in the channel to convey process water to treatment at the 15 Plant Oil/Water Separator prior to discharge to DELCORA (Brown & Root, 1993). Middle Creek and Walker's Run were enclosed and covered throughout the facility to the former pH Basin dam, with an open remnant draining to the Delaware River in AOI 7.

The concrete dam is located in the vicinity of the Middle Creek Interceptor Trench Recovery System (AOI 5) which recovers LNAPL in the area of the AOI 5/AOI 7 boundary. Two groundwater interceptor trenches (Trench A and Trench B) were installed in the area between the API Separator and Middle Creek in December 2008. Three recovery wells were installed within the two trenches. Total fluids are pumped from each recovery well through a line to a common vault from which it is then pumped to the 15 Plant Separator. The system was started in the beginning of June 2009.

Trenches are field verified as dewatered to confirm system operation on a weekly basis (Langan, 2012).

2.4.2 Adjacent Properties

AOI 7 is bordered by the DVW (also known as General Chemical Corporation and Honeywell), which is a former chemical manufacturing plant located in Claymont, Delaware and Marcus Hook, PA. The DVW consists of approximately 100 acres, which is divided by Route 13 into two separate plants, referred to as the "DVW North Plant" and "DVW South Plant". The DVW South Plant is located adjacent to the MHIC AOI 7 site. Two-thirds of the DVW North Plant is located in Pennsylvania with the remainder situated in Delaware. Virtually all of the DVW South Plant is located in Delaware. A drainage channel referred to as "the sluiceway" traverses the southern portion of the DVW South Plant and discharges to the Delaware River approximately 2,500 feet downstream of Middle Creek. A variety of inorganic chemicals and pesticides were manufactured at the DVW during different periods since it began operation in the late 1890s (USEPA, 2016b).

The DVW facility manufactured chemical products including pesticides (DDT and DDD or DDE), organic and inorganic acids, and various other specialty chemicals (MACTEC, 2005). General Chemical Corporation (GCC) acquired the DVW from Allied Signal (now known as Honeywell International Inc.) in 1986. Allied Signal retained ownership of several contiguous parcels of property upon which chemical operations were conducted and continue today. As a result of a Reorganization Plan, GCC assumed cleanup responsibility for most of the soils in the DVW South Plant and Honeywell assumed responsibility for cleanup of the remainder of the DVW (USEPA, 2016b).

The DVW South Plant (South Plant) which includes former landfill (SWMU 9) is the most relevant to AOI 7 as it represent background conditions and potential off-site impacts to AOI 7. SWMU 9 was used for disposal of pesticides and related wastes, materials from DDT and DDD production, and laboratory samples disposal. SWMU 9 started as a settling pond in the area adjacent to AOI 7 (called Parcel 1) and was constructed by placing a bulkhead along the Delaware River and placing alum mud for dewatering. Exploratory borings in the 1970s detected up to 5,810 milligrams per kilogram (mg/kg) of lead in the soil and fill materials in the vicinity of SWMU 9). The Lower Sluiceway, a primary discharge point for the former DVW South Plant is located on the west side of SWMU 9.

On September 19, 2008, USEPA Region III collected limited Delaware River sediment samples within the tidal mudflats, adjacent to the GCC property (South Plant) and the DVW SWMU 9. The sampling data indicated the presence of pesticides (primarily DDT and its isomers) and several metals (primarily arsenic and lead) (Cummings/Riter Consultants, Inc. 2010).

In September 2011, USEPA issued an Administrative Order to Honeywell International Inc., which required a facility wide investigation of the DVW facility. The Administrative Order was issued pursuant to Section 3008(h) of RCRA. The requirements of the order include:

- Interim Measures/Stabilization to achieve the initial goal of controlling ground water releases and controlling current human and ecological exposure to contaminated media

- RFI, to provide more in-depth information about SWMUs
- Corrective Measures Study (CMS) if warranted, to propose final cleanup actions needed

In response to this Order, the following documents were submitted to USEPA on Corrective Action activities:

- IRM Alternatives Assessment for Lower Sluiceway (March 2012) Maintenance Storm Sewer Cleaning (2012) – accumulated sludge, sediment and debris were removed from storm sewer pipes and associated laterals; video inspection of lines; lines deemed no longer necessary by Honeywell were closed in place by excavation and backfilling with concrete.
- Completion of IRM for Upper Sluiceway (2013) – Dredged (soft sediment) and covered (geotextile fabric and minimum 6-inch thick AquaBlok® layer) to mitigate for potential release of source material (containing DDx, arsenic and lead) into lower sluiceway and Delaware River.
- An RFI work plan to investigate additional SWMUs was approved in July 2015.

As a result of investigations on the DVW property, sediment investigations extended down the sluiceway and into the Delaware River. In its investigation of sediments in the Delaware River, Honeywell identified arsenic, lead and DDx (the sum of DDD, DDE and DDT) as key constituents detected and concentrations of potential concern. Environ, on behalf of Honeywell, has presented a set of proposed preliminary remediation goals for DDx, arsenic and lead in 2012 (see Section 3.2.2). Supplemental investigations were performed in the Delaware River adjacent to SWMU 9 and into the mouth of Middle Creek. The following reports were submitted to support this work:

- Delaware River Sediment Sample Collection (October 2012) – Further evaluation of shoreline sediment (DDx, arsenic, and lead).
- Evaluation of Sediment Remediation Goals (2012) – Proposed IRM for the pesticides and metals in nearshore sediments of Delaware River; February 2011.
- Sediment Sampling and Analysis Results Chemtrade Solutions LLC and Honeywell International Inc. Claymont, Delaware, August 2015 - Sediment results for DDx, arsenic and lead.
- Supplemental Study Area Sediment Investigation Work Plan. Delaware Works Property Claymont, Delaware, July 2016 - Investigation of downstream sediments for DDx.
- Supplemental Study Area Sediment Investigation Report. Delaware Works Property. Claymont, Delaware, Draft February 2017.

The North Plant portion of the DVW facility received a Statement of Basis from USEPA for RCRA Corrective Action in 2016 (USEPA, 2016a).

2.5 Strategy and Technical Approach

The RCRA Corrective Action process uses the RFI to identify if releases of hazardous substances have occurred from SWMUs or AOCs. The RFI characterizes sources of hazardous constituents, identifies and assesses migration pathways and determines impacts to receptors. The information provided in the RFI will identify media and locations requiring further evaluation to determine if corrective action is necessary to address unacceptable risks to the identified receptors.

The strategy used for the RFI is to investigate and characterize conditions in AOI 7 based on the process outlined in the CAF.

2.5.1 Understanding of Facility Conditions and Exposures

As documented in the CAF, USEPA and Sunoco/Evergreen identified the following key points regarding conditions at the facility and objectives for the corrective action:

- Land use/reasonably expected future land use is expected to be industrial.
- The future use of the facility is expected to include products storage, propylene splitting, shale gas processing, and gas storage/transfer.
- Existing background conditions or off-site impacts may be considered as part of the evaluation of the facility.
- Historical data were used to design the remedial investigation activities.
- The highest beneficial use of groundwater is as a recharge to surface water. There are no other identified uses for groundwater.
- Evergreen will coordinate directly with the DNREC tank program as required, separate from the RFI process.
- There are no toxicity/criteria changes currently expected but they will be addressed if they arise.
- There are no risk range issues expected currently but they will be addressed if they arise.
- One or more Environmental Covenant(s) will be sought for the site as part of remedy completion.

Thus, the current and future use for AOI 7 is industrial. Environmental Covenants will be used to enforce these exposure assumptions. The characterization and assessment of these media are to be performed to support AOI 7 meeting the Corrective Action Objectives (CAOs) discussed in Section 2.6.

2.5.2 Technical Approach

The technical approach used in the RFI was to evaluate historical information and data to design the RFI, identify potential compounds of concern (COCs) and routes of exposure related to operations in AOI 7, complete an investigation of each environmental media to assess conditions in comparison to the Screening Levels to identify what COCs and media of concern may need to be further evaluated in a risk assessment and, as appropriate, in a CMS. This section provides an overview of the technical approach for the AOI 7 RFI.

2.5.2.1 Evaluation of Historical Operations

Historical information was available for AOI 7 prior to the RFI from various investigations and remedial activities completed in and around AOI 7 which were reviewed to develop the approach for the RFI. The documents reviewed in preparation of this RFI are listed in the reference section.

Section 2.3.1.1 presents more detail on the historical operation and lists previous investigations in AOI 7.

2.5.2.2 Compounds of Concern

The facility has been engaged in the refining of petroleum since the beginning of operations. The Current Conditions Report (CCR) stated that COCs in groundwater and soil are generally petroleum hydrocarbons (Langan, 2012). The CAF further refines the COCs for the facility to include: lead, 1,2-dichloroethane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, cumene, ethylbenzene, ethylene dibromide, methyl tertiary butyl ether, toluene, xylenes, anthracene, benzo(a)anthracene, benzo(g,h,i)perylene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, fluorene, naphthalene, phenanthrene, and pyrene. Additional compounds are to be added to this list dependent upon localized operations with in the AOIs, as necessary.

Due to AOI 7's location in Delaware, the analytical scope for the RFI was designed to include both USEPA RCRA and DNREC Hazardous Substance Cleanup Act (HSCA) constituents of interest. Environmental media (soil, groundwater, surface water and sediment) were generally analyzed for VOCs, semi-volatile organic compounds (SVOCs), metals, pesticides and polychlorinated biphenyls (PCBs).

2.5.2.3 Background – Non-Facility Sourced Impacts

Middle Creek surface water and sediment, as well as soils and groundwater in AOI 7, may be impacted by off-site groundwater, historical overland flow, sediment transport or historic operations from the adjacent Delaware Valley Works (DVW), which is the former Honeywell and General Chemical Site. AOI 7 directly borders waste disposal and discharge facilities on the adjacent DVW property. Due to the history of filling activities and the tidal nature of the Delaware River and Middle Creek, contaminant migration from DVW to AOI 7 has been identified as a source of impacts to AOI 7. Pesticide constituents (e.g., DDx and BHC isomers) have been identified in soil, groundwater, surface water and sediment of the Marcus Hook Industrial Complex; these constituents were not used or stored at the Property. DDD was known to have been manufactured, among other pesticides and chemicals, at the adjacent DVW property. Arsenic is also a common inorganic pesticide that has been detected throughout the DVW property. Impacts from the discharge of pesticides, notably those of the DDx series, have been traced from the upland sections of DVW to sediments in the Delaware River including those at the mouth of Middle Creek.

2.5.2.4 Potential Receptors

No residential or recreational use will occur at the facility due to site-operations and security. Potential receptors for soil are industrial workers and construction workers at the AOI 7 portion of the facility. No groundwater is used or is expected to be used at the facility. As previously discussed, the crystalline bedrock underlying the unconsolidated material at AOI 7 is not considered to be a groundwater receptor. A well survey was completed for the Pennsylvania portion of the Facility in 2016 which documented no downgradient groundwater use within 0.5 miles of the facility. The Delaware portion of the facility is bordered by the DVW facility along the western boundary, which has no potable production wells downgradient of the Facility.

Environmental covenants will provide institutional control for non-residential uses of the property. The ultimate receptor of groundwater is surface water of Middle Creek and the Delaware River. Potential receptors from surface water in the Delaware River are the consumption of fish from recreational fishing and ecological receptors in Middle Creek. There are no current or planned buildings therefore there are no indoor air receptors in AOI 7.

2.5.2.5 Screening Levels

The screening levels used as part of the RFI include USEPA's November 2018 Industrial/Commercial Regional Screening Levels (RSLs) for soil, Maximum Contaminant Levels (MCLs) for groundwater, Delaware River Basin Commission (DRBC) surface water criteria for surface water and the Region 3 Biological Technical Assistance Group (BTAG) criteria for sediment. These screening criteria are summarized in the CAF, which is included in Appendix A.

Middle Creek surface water and sediment, as well as soil, groundwater and sediment in AOI 7, may be impacted by off-site groundwater, historical off-site overland flow, or historic off-site operations. Data from off-site locations were reviewed to determine if background considerations are relevant to the investigation of AOI 7.

The screening process for the AOI 7 RFI is further described below by media.

2.5.2.5.1 Soil

The soil characterization data in this RFI were compared to screening criteria that are based on the USEPA's November 2018 Industrial/Commercial Regional Screening Levels (USEPA, 2018a&b). The USEPA RSLs criteria assume incidental soil ingestion, dermal contact with soil, and inhalation of vapors or particulates from exposed soil and are appropriate based on current and reasonably expected future land use at the site. The generic risk-based criteria used for screening were calculated based on cancer risk of 10^{-6} and a hazard quotient (HQ) of 0.1 and 1. They are also derived from exposure factors that reflect conservative assumptions about the magnitude, frequency, and duration of exposures, which in combination are intended to provide estimates of exposures that are higher than actual exposures to a large portion (90 to 99 percent) of the population. The available RSL for thallium was based on an appendix value identified from an USEPA Office of Research and Development Provisional Peer Reviewed Toxicity Value (PPRTV) in which the USEPA did not have a high level of confidence and as such the USEPA has only recommended that these values be used for screening purposes and not the calculation of cleanup levels. Therefore, while thallium is reported in the data tables it was not carried forward in any of the additional risk screening for human health. It was evaluated for ecological receptors as is discussed in the SLERA.

Potential exposure of routine workers to lead in soil was evaluated separately from the assessment for other constituents because USEPA (2003) evaluates the significance of lead exposures using blood lead level as an index of exposure, rather than in terms of cancer risk or non-cancer HQ. USEPA's recommended level for routine worker exposure to lead in soil in the 0- to 2-foot below grade interval is 2,240 mg/kg (USEPA 2009b), which is based on a blood lead modeling approach designed to be protective of potential exposures to soil lead in industrial settings. A Human Health Risk Assessment Report (February 24, 2015) submitted by Evergreen to PADEP, presented the development of a risk-based site-specific standard for (SSS) for lead in soil (Langan, 2015). The PADEP approved the report (correspondence of May 6, 2015) and a non-residential direct contact site-specific numerical standard for lead of 2,240 mg/kg in soil at 0 to 2 ft. bgs. Using the same methodology, a value of 5,995 mg/kg was calculated for lead in the greater than 2-foot below grade interval in AOI 7. The supporting information for both sets of lead screening values is included in Appendix K.

2.5.2.5.2 Groundwater

In accordance with the CAF, the groundwater monitoring data collected during the RFI were screened against the MCLs. These groundwater screening criteria are designed to be protective of potential exposures via drinking water use and represent highly conservative screening criteria for evaluating groundwater that is not a current or reasonably expected future drinking water supply.

The CAOs for groundwater are based on not causing an exceedance of the DRBC surface water criteria (protection of human health from fish ingestion) in the Delaware River, as further described in Section 2.5.2.5.4. For groundwater discharging to the Delaware River, a CorMix Model was created for the facility to determine the mixing factor to be applied to the surface water screening levels based on groundwater discharge to surface water that would not result in an exceedance of the surface water screening levels. The details of the CorMix modeling are described in Appendix M.

2.5.2.5.3 Sediment

No human contact exposure scenario applies to sediments in Middle Creek from industrial activity at the facility. There are however potential ecological exposures to sediments in Middle Creek. The sediment data collected during the RFI were compared with Region 3 generic freshwater sediment criteria from BTAG (USEPA, 2006a).

2.5.2.5.4 Surface Water

Surface water quality in the Delaware River and its tributaries is regulated by the DRBC. DRBC has published Water Quality Regulations (DRBC, 2013), which include concentrations protective of human health for surface water and fish ingestion. There is no surface water consumption in the river near AOI 7, therefore the DRBC fish consumption criteria were used as the screening levels for surface water. Where values were not available based on fish consumption, DRBC criteria for protection of freshwater aquatic life (chronic exposures) were used for the screening levels.

2.6 Corrective Action Objectives

The CAOs for the specific environmental media at the facility are included in the CAF (Appendix A). These are presented below for each environmental medium as applicable to AOI 7; additional CAOs are included in the CAF for other areas of the facility.

The CAOs for each environmental media are presented in Tables 4.1 to 4.18 for soil and Table 4.21 for groundwater (sediment and surface water were evaluated in the SLERA, Appendix N) and are discussed below.

2.6.1 Soil

The CAOs identified in the CAF for soil include:

- Eliminate any direct contact exposures to soils greater than the applicable Industrial RSL based on risk range of 10^{-4} to 10^{-6} and HI of 1 as listed in Table 2a of the CAF (Appendix A).
- Prevent exposure to lead impacted soils above the calculated site-specific standard listed in the Table 2a in the CAF (Appendix A) (calculations documented in Appendix K).
- Mitigate exposures to LNAPL during intrusive activities by construction workers in the areas impacted by LNAPL.
- Prevent future residential land use based on current and future use risk exposure assumptions.

A Human Health Risk Assessment was completed for all constituents in soil, other than lead, as discussed in Appendix O and summarized in Section 5.5. The CAOs presented in the CAF for soil are based on a 10^{-4} risk level and a HI of 1. The values developed for lead in surface and subsurface soil (as documented in Appendix K), serve as CAOs for soil.

2.6.2 Groundwater

The CAOs identified in the CAF for groundwater include:

- Prevent inhalation (unless further evaluated and shown to be acceptable by a vapor intrusion assessment), ingestion or dermal exposure above non-residential standards listed in Appendix A
- Prohibit use of groundwater except for what is required for sampling and remediation
- Prevent off-site migration or discharge of LNAPL
- Prevent off-site migration of groundwater to the Delaware River at concentrations that would exceed the DRBC fish ingestion criteria
- Prevent groundwater discharging to Middle Creek that results in concentrations exceeding the DRBC fish ingestion criteria in the Delaware River

The CAOs for groundwater are based on not causing an exceedance of the surface water criteria in the receiving surface water body. For groundwater discharging to the Delaware River, a CorMix Model was created for the facility to determine the mixing factor to be applied to the surface water screening levels based on groundwater discharge to surface water that would not result in an exceedance of the surface water screening levels.

The screening levels and CAOs for groundwater are summarized in Table 4.21.

2.6.3 Indoor Air

The CAOs identified in the CAF for indoor air are:

- Comply with the OSHA Permissible Exposure Limits (PELs) for industrial use where employees are covered by OSHA, as listed in the tables in the CAF in Appendix A

- Prevent human exposure to non-OSHA covered workers from the vapors exceeding the applicable USEPA non-residential indoor air standards as listed in Appendix A, from LNAPL or residual soil and groundwater contamination through vapor mitigation controls

It should be noted that no current or planned occupied structures were identified at AOI 7 during the development of this RFI.

2.6.4 Surface Water

The CAOs identified in the CAF for surface water are:

- Prevent any impacts to the Delaware River that cause surface water concentrations to exceed the DRBC fish ingestion standards listed in the tables in Appendix A
- Prevent unacceptable ecological impacts to surface water in Middle Creek as determined by an ecological risk assessment

2.6.5 Sediment

The CAO identified in the CAF for sediment is:

- Prevent unacceptable ecological impacts to sediment in Middle Creek as determined by an ecological risk assessment (see Appendix N). A SLERA was completed for AOI 7, which assessed risk associated with sediment conditions in Middle Creek. It should be noted that Remediation Goals (RGs) were developed for use on sediment in Middle Creek for DDx and arsenic by Honeywell (Appendix D). Evergreen also developed PRGs for lead in sediment for Middle Creek as documented in Appendix K.

3. RFI Investigation Program

3.1 Investigation Scope and Activities

The following sections summarize the RFI activities completed in AOI 7 in 2015 and 2016. The scope of the work for the AOI 7 RFI is described in the Work Plans included in Appendix E. Field work was performed in accordance with Evergreen's *Quality Assurance/Quality Control Plan and Field Procedures Manual (*Appendix H). Analyses of samples were conducted by Lancaster Laboratories. Laboratory analytical reports are included in Appendix I.

Environmental media were investigated in AOI 7 by the following areas (as shown on Figure 3.1):

- SWMU 23/24- Old Sludge Basin/Old Decant Basin - soil and ground water
- SWMU 27 – Phillips Island - soil and groundwater
- Middle Creek Area - surface water, sediment. Soil and groundwater immediately adjacent to Middle Creek were also evaluated
- 17 Plant Area – located north of Middle Creek - soil and groundwater

- Area South of Middle Creek - soil and groundwater
- Area West of Middle Creek - soil and groundwater

As stated previously, since there were no indoor air receptors, no soil vapor or air samples were collected as part of the RFI. Figure 3.1 shows the locations of the samples collected during the RFI and these activities are summarized in Table 3.1.

3.1.1 Soil

Soil samples were collected during the boring and monitoring well installations in accordance with the Work Plan. The general strategy for the investigation was to characterize soil in the intervals from 0 to 2 ft. bgs and greater than 2 ft. bgs as distinct intervals. Soil samples were collected primarily in the unsaturated zone; however some samples were collected in the saturated zone during monitoring well installations. The work plans in Appendix E summarize the soil sampling rationale, and soil boring logs are included in Appendix F.

Soil samples were analyzed for Target Compound List (TCL) VOCs, TCL SVOCs, TCL pesticides and PCBs and Target Analyte List (TAL) inorganics. All soil analytical results are summarized in Tables 4.1 through 4.18, which compare the results to the screening levels and the CAOs.

3.1.1.1 SWMU 23/24 Old Sludge Basin/Old Decant Basin

In 2015, a soil investigation was performed to identify the horizontal and vertical limits of SWMU 23/24 using visual cues (i.e., purple color of soils based on the previous remedial activities) and to characterize soils at those limits. A total of 17 soil boreholes were completed during the initial phase of work in 2015 (AOI7-BH-15-001 to AOI7-BH-15-012, plus AOI7-BH-15-027 to AOI7-BH-15-031), with completion depths ranging from 4 to 28 ft. bgs. A total of ten soil samples were collected in SWMU 23/24 during the first phase of investigation from 5 to 7 ft. bgs to 14.5 to 16.5 ft. bgs intervals, and the remainder of the characterization was based on visual observations. In addition to the analyte list above some soil boring locations had selected intervals sampled for gasoline range organics (GRO), diesel range organics (DRO), oil range organics (ORO), and grain size.

The assumption was made that purple-colored soil resulting from the historical stabilization efforts would coincide with the limits of SWMU 23/24; however, the extent of the purple color was found to go beyond the extent of SWMU 23/24. Therefore, during 2016, supplemental samples were collected to characterize soil in SWMU 23/24. During the supplemental sampling event, 19 surface soil samples and ten subsurface soil samples were analyzed for selected constituents to characterize shallow soil not sampled in 2015 and support delineation from the 2015 sampling. Soil samples were collected in adjacent portions of AOI 5 for the investigation of SWMU 87-94 (No. 15 Separator) as part of a Remedial Investigation in AOI 5. The two locations closest to SWMU 23/24 (AOI5-BH-16-035 and -038) provided information that was used to delineate constituent concentrations in soil in SWMU 23/24.

3.1.1.2 SWMU 27 Phillips Island

In 2015, a total of 13 soil boreholes were completed during the investigation (AOI7-BH-15-013 to AOI7-BH-15-026), with completion depths ranging from 16 to 32 ft. bgs. A total of ten soil samples were collected in SWMU 27 ranging from 6 to 7 ft. bgs to 18 to 20 ft. bgs depth intervals. Select intervals in soil borings were sampled for GRO-DRO-ORO and grain size. Soil was sampled during the installation of the three monitoring well clusters (MW-527, MW-528, and MW-533) in SWMU 27. Five shallow soil samples were collected from 0 to 2 or 1 to 3 ft. bgs intervals and six subsurface soil samples were collected from 5.5 to 6.5 ft. bgs to 28.5 to 29.5 ft. bgs intervals. Four soil borehole locations (MW-145, B-PH2, B-PH3, and B-PH11) completed during the Phillips Island investigations reported by URS (URS, 2005) were used to correlate soil data collected during the RFI in SWMU 27 as discussed in Section 4.1.

3.1.1.3 Middle Creek Drainage Area

Soil samples were collected during monitoring well installations completed immediately north, south and east of Middle Creek (MW-536, MW-537, MW-538, MW-539, MW-540, and MW-541). Seven surface soil samples were collected from 0 to 2 or 1 to 3 ft. bgs intervals (due to gravel or concrete in the 0 to 1 ft. interval) and eight subsurface samples were collected from 1.5 to 3.5 ft. bgs to 11.5 to 12.5 ft. bgs intervals.

3.1.1.4 Area South of Middle Creek

Twenty two soil samples were collected from seven monitoring wells (MW-529, MW-530, MW-531, MW-532, MW-534, MW-561, and MW-562) in the area south of Middle Creek. Seven surface soil samples were collected from 0 to 2 or 1 to 3 ft. bgs intervals and fourteen subsurface samples were collected from depths ranged from 7 to 8 ft. bgs to 28.5 to 29.5 ft. bgs intervals.

In addition to the soil data collected during the RFI, two shallow soil samples and two subsurface soil samples were collected at the former Ethylene Complex Warehouse, designated as ECWH-01 NW (0.5 to 1.0 ft. bgs.), ECWH-02 E(2.5 to 3.0 ft. bgs), ECWH-03 W(1.5 to 2.0 ft. bgs) and ECWH-04 SE (2.0 to 2.5 ft. bgs) samples on August 18, 2015. The data from these analyses are discussed in Section 4.1 with the results from the RFI soil analyses.

3.1.1.5 Area West of Middle Creek

Soil samples were also collected during the installation of four monitoring wells (MW-557, MW-558, MW-559, and MW-560) on the west side of Middle Creek and one well at the western property boundary northwest of the bend in the creek (MW-551) along the western property boundary. Five surface soil samples were collected from the 0-2 ft. bgs interval and five subsurface soil samples from intervals ranging from 2 to 5 ft. bgs to 10 to 11 ft. bgs.

3.1.1.6 17 Plant Area

Fourteen soil samples were collected from 7 soil borings (AOI7-BH-16-001 through -007) in March 2016 in the northern portion of AOI 7 as a part of the investigation of 17 Plant after its decommissioning and demolition in the area north of Middle Creek. AOI7-BH-16-001 through -007 were installed in a grid pattern between the Conrail tracks and Tank 626, as shown on Figure 3.1.

Seven surface soil samples were collected from 0 to 2 ft. bgs and seven samples from a subsurface interval selected at depths up to 5 ft. bgs.

3.1.2 Groundwater

3.1.2.1 Monitoring Well Installation

A total of 29 groundwater monitoring wells were installed in AOI 7 during the RFI using hollow stem augers. The locations of the new monitoring wells are shown on Figure 3.1. Soil samples were collected during the monitoring well installations as is described in the previous section. Monitoring well installation logs and stratigraphic logs are presented in Appendix F. Delaware well installation permits are also included in Appendix F.

The following summarizes the monitoring well installations in relation to the areas identified in AOI 7.

3.1.2.1.1 SMUW 23/24 Old Sludge Basin/Old Decant Basin

No monitoring wells were installed during the RFI in the SWMU 23/24 area, however there were a number of pre-existing wells including, MW-182, MW-184, and MW-187 installed directly to the south of SWMU 23/24 on the north bank of Middle Creek. These were used to assess groundwater conditions south of SWMUs 23/24 as part of the RFI.

3.1.2.1.2 SWMU 27 Phillips Island

Three monitoring well clusters (MW-527U and L, MW-528U and L, and MW-533U and L) were installed near the Delaware River in SWMU 27 during the RFI. Well screens were installed at two depths (designated as U and L) to evaluate flux from groundwater to the Delaware River and to allow the measurement of vertical gradients. The screen intervals were generally set at 5 to 15 ft. bgs to investigate water table conditions (U designations) and at 20 to 30 ft. bgs (L designation) to investigate deeper conditions with an adequate vertical separation from the shallower screened wells. MW-527 and MW-528 were installed at the river front and MW-533 was installed approximately 250 feet north of MW-528.

3.1.2.1.3 Middle Creek Area

A total of six monitoring wells were installed along Middle Creek to investigate groundwater impacts adjacent to the Middle Creek and evaluate groundwater/surface water interaction, as shown on Figure 3.1. These monitoring wells were installed with screens set at 5 to 15 ft. bgs. Two wells (MW-536 and MW-537) were installed on the east side of the downstream section of Middle Creek. Two monitoring wells (MW-538 and MW-539) were installed on the south side and two wells on the north side of the upstream segment of Middle Creek.

3.1.2.1.4 Area South of Middle Creek

Eight wells were installed at four locations along the bank of the Delaware River (MW-529U and L, MW-530U and L, MW-531U and L, and MW-532U and L) and at a fifth location (MW-534U and L) approximately 250 feet to the north of MW-530. The upper and lower depth intervals followed the same rationale as noted above for SWMU 27. Two additional shallow wells (MW-561 and MW-562) were installed in the central portion of the former Ethylene Complex with screen depths generally from 5 to 15 ft. bgs.

3.1.2.1.5 Area West of Middle Creek

Four wells (MW-557, MW-558, MW-559, and MW-560) were installed on the western side of the creek to evaluate groundwater quality from the off-site DVW (Honeywell/General Chemical) property. The screen intervals were generally set at 5 to 15 ft. bgs to investigate water table conditions.

3.1.2.1.6 17 Plant Area

No wells were installed during the RFI in the 17 Plant Area; however, there were two pre-existing wells in this area, monitoring wells MW-292, and MW-552 (Figure 3.1), which were sampled during the RFI.

3.1.2.2 Tidal Influence Study

Tidal influences on groundwater elevations were investigated by continuous monitoring of groundwater levels using transducers in 15 monitoring wells (MW-26, MW-28, MW-29, MW-30, MW-36, MW-141, MW-214, MW-320, MW-323, MW-501, MW-527, MW-528, MW-530, MW-532, and MW-533) spaced evenly along the along the Delaware River front in October 2015. Monitoring wells were evaluated prior to selecting the locations used to complete this study to ensure that LNAPL was not present, the monitoring well was functional, and the groundwater table was within the screened interval. No recovery wells were used as part of this study. Thirteen of the monitoring wells were located within 100 feet of the Delaware River, while two of the monitoring wells (MW26 and MW533U) were set back approximately 250 to 300 feet from the riverfront to assess the difference in tidal impact with distance from the Delaware River. In addition, a 1.5-inch PVC stilling well was set up at Dock 3 to gauge the water level in the Delaware River for comparison. Transducers were deployed at each location from September 30, 2015 to November 5, 2015. Synchronized water level measurements were collected every 15 minutes at each transducer location. Figure 3.1 shows the locations used in the Tidal Study.

Factory calibrated level TROLL 500 model transducers were selected to conduct this study. Since this model is vented to the atmosphere, no correction for barometric pressure was required to be made during the tidal study. Transducers were configured to record the depth of water above the transducer in feet. The depth of the transducer and the depth to water below top of riser were recorded during installation and one week into the testing for comparison to the real-time transducer data to ensure the transducers were reading accurately in the field. The transducers were secured in the monitoring wells by a cable and bracket to prevent the transducer depth from changing during the study period. After the study was completed, the data was collected from the loggers using a handheld Rugged Reader PC. The data was converted from the transducer files to Excel files using the WinSitu software program to graph and interpret the results. GHD entered the top of riser elevation survey data and one depth to water measurement collected in the field so the WinSitu software could convert the data set to mean sea level. The converted data was then verified using a depth to water measurements collected at installation of the transducers on September 30, 2015, one week later (October 6) and on the day of transducer retrieval (November 5).

3.1.2.3 Slug Testing

Aquifer testing was completed at four wells (MW-36, MW-214, MW-320, and MW-532U) used in the tidal study to obtain data to calculate site-specific hydraulic conductivity (K) values which were used in support of CorMix model described in Section 4.4.1. The wells were selected to represent conditions along entire shoreline of the Delaware River within the Facility, wells with no non-aqueous phase liquid present, and wells with screen intervals across the water table.

The aquifer testing consisted of the addition and withdrawal of solid PVC slug with a known volume (Slug Testing). The slug tests were completed prior to the installation of transducer installation for tidal study described in Section 4.2.1.1. Slug tests were performed using solid PVC slugs. Slug in and slug out tests were performed with water levels measured by transducers on a 0.5-second interval. Data were downloaded from the transducers and entered in excel tables. Analysis was performed by Bouwer and Rice method as described in the memorandum in Appendix L.

3.1.2.4 Groundwater Monitoring Well Gauging

Evergreen performs facility-wide groundwater gauging in monitoring wells in October of each year. During this gauging, the condition of wells is inspected and the depth to groundwater from a surveyed reference point is obtained as is depth to LNAPL (if present). The Facility-wide groundwater contours from the October 2016 gauging event are summarized on Figure 2.6 and are discussed further in Section 4.2.1. In addition to the annual events, groundwater and LNAPL level measurements were collected in AOI 7 during both of the RFI groundwater sampling events (September 8 to 11, 2015, January 20, 2016 and June 28 to July 7, 2016). The results from the groundwater gauging are presented in Section 4.2.1.

3.1.2.5 Groundwater Sampling and Analysis

Groundwater sampling was performed at each of the 29 newly installed wells following development and recovery in September 11, 2015 and January 20, 2016. The newly installed monitoring wells are shown on Figure 3.1. Another round of groundwater sampling was performed at 42 wells in late June and early July 2016. This second sampling event included all of the RFI installed wells plus additional wells along Middle Creek and along the Delaware River. Groundwater sampling was performed by low flow methods for PPL VOCs, SVOCs, pesticides (June/July 2016 event only), PCB Aroclors (2015 event only) and metals in accordance with the SOPs in Appendix H. All groundwater samples collected for metals analysis were field filtered.

The following summarizes the groundwater sampling activities per the identified subareas of AOI 7 in relation to the groundwater sampling activities.

3.1.2.5.1 SWMU 23/24

Monitoring wells MW-182, MW-184, and MW-187, shown on Figure 3.1, were sampled during the June/July 2016 monitoring event. The monitoring wells which are also on the north bank of Middle Creek and were assessed as part of the Middle Creek Area evaluation as discussed below.

3.1.2.5.2 SWMU 27 – Phillips Island

Six monitoring wells (MW-527U, MW-527L, MW-528U, MW-528L, MW-533U, and MW-533L) were sampled in September 2015 and June/July 2016 monitoring events.

3.1.2.5.3 Middle Creek Area

The wells installed along Middle Creek during the RFI (MW-536, MW-537, MW-538, MW-539, MW-540, and MW-541) were sampled in September 2015. In addition, during the 2016 monitoring event, the wells along Middle Creek were sampled in conjunction with surface water sampling in Middle Creek to assess groundwater interaction with surface water. Nine wells (MW-537, MW-509, MW-293, MW-48, and MW-541, plus the four wells on the west side of Middle Creek) located along the downstream (north-south) reach of Middle Creek, were sampled on the same day as the surface water samples are collected in the same reach, with the timing targeted to reflect low tide conditions. Sampling along the upstream (east-west) reach from eight monitoring wells (MW-538, MW-539, MW-540, MW-182, MW-184, MW-187, MW-277, and MW-132) were completed on a second day, also targeted to reflect low tide conditions and coincident with the surface water sampling in the upstream reach. These wells were sampled over two days due to the tidally influenced changes in water levels observed in Middle Creek and adjacent monitoring wells.

3.1.2.5.4 Area South of Middle Creek

Groundwater samples were collected from eight monitoring wells installed in four clusters along the Delaware River (MW-529U and L, MW-530U and L, MW-531U and L and MW-532U and L) following installation of the wells in September 2015. MW-534U and L were not initially sampled after installation due to the presence of LNAPL in those wells, but were sampled during the June/July 2016 sampling event. Groundwater samples were collected from monitoring wells MW-561 and MW-562 following their installation in January 2016. All twelve of these wells were sampled during the June/July 2016 sampling event. During the June/July 2016 event, groundwater was collected beneath LNAPL (where present) following Evergreen SOPs included in Appendix H. Four wells that were present prior to the RFI (MW-53, MW-55, MW-56, and MW-57) were also included in the June/July 2016 sampling event.

3.1.2.5.5 Area West of Middle Creek

The five wells west of Middle Creek (MW-551, MW-557, MW-558, MW-559, and MW-560) were sampled after their initial development and the wells had stabilized (September 2015 for MW-551 and January 2016 for the remainder). All five of these wells were sampled during the June/July 2016 sampling event. MW-557, MW-558, MW-559, and MW-560 were sampled in conjunction with the Middle Creek sampling event described above in Section 3.15. Groundwater monitoring wells MW-48 and MW-47 are also west of Middle Creek or northwest of the bend in the creek in areas that are identified as upgradient of the creek. These two wells were sampled in June/July 2016.

3.1.2.5.6 17 Plant Area

Two monitoring wells (MW-292 and MW-552) were sampled in the June/July 2016 sampling event.

3.1.3 Seep

During the initial groundwater investigations in 2015, an area of seepage was observed on the eastern bank of Middle Creek in the vicinity of SW-002/SED-002 sampling station. This discharge is an intermittently observed seepage and was not present at every observation event. A sample of seep water (identified as AOI7_MHIC_DE_MC_SEEP) was collected on September 1, 2015 at the location shown on Figure 3.1. The sample was submitted for TCL VOC, SVOC, pesticides, PCB Aroclors, and total and filtered TAL metals analyses.

3.1.4 Sediment

Characterization of the sediment in Middle Creek was performed by the collection of samples at ten stations spaced out along the 2,500-foot length of the creek from the dam to the mouth as shown on Figure 3.1. Five of the stations were from the downstream reach of the creek (SED-001, SED-002, SED-003, SED-004, and SED-005) and five were from the upstream section (SED-006, SED-007, SED-008, SED-009, and SED-010).

Samples collected in 2015 were obtained from the 0- to 6-inch interval to assess the biologically active (benthic) zone as well as the 6 to 24 inches interval to evaluate sediments that might be exposed as the result of corrective action activities. Additional investigation of the 0- to 6-inch depth interval was performed in July 2016 at the same ten locations sampled in 2015 in order to support an ecological risk assessment. The 2016 sampling included 34 parent and alkylated PAHs (Method 8270C SIM) recognized by EPA as having a combined narcotic effect on benthic receptors. Samples were also submitted for acid volatile sulfides and simultaneously extracted metals (AVS/SEM) to determine how much of the divalent metals present in the sediments are present in a biologically available form. Sediment samples at stations SED-005, SED-006, SED-007, SED-008, SED-009, and SED-010 were also sampled for PCBs to verify conditions after an erroneous detection was obtained in 2015 for a duplicate sample at SED-007.

3.1.5 Surface Water

The initial sampling of surface water was performed in Middle Creek for preliminary characterization on August 17 and 20, 2015 at the same ten stations where sediment was sampled (identified as SW-001 through SW-010) as shown on Figure 3.1. All of these samples were collected at above mid tide stage, that is after the mid-point between low tide rising to high tide and before the mid-point between high tide falling to low tide. A second round of surface water samples was collected on June 29 and 30, 2016 at the same locations to correlate shallow groundwater conditions adjacent to Middle Creek (as described in Section 3.1.2.5) to surface water conditions. In the second round sampling, surface water was collected in the low tide cycle (all were collected prior to the mid rising tide or after the mid falling tide point) at the same time as groundwater was sampled at water table monitoring wells adjacent to the creek. A third round of surface water sampling was performed on September 12, 2016 at four locations (SW-002, SW-004, SW-006, and SW-008) to provide additional information on metals in surface water at mid tide (targeted at mid stage rising and mid stage falling) average conditions.

The 2015 samples for metals analyses were submitted unpreserved to the laboratory to allow filtration prior to analysis. The 2016 samples were field filtered through a 0.45 micron filter (samples were poured into a location-dedicated Teflon bailer with an inline filter attached to the discharge) into a sample container with preservatives prior to submittal to the laboratory.

Surface water samples were submitted for analysis of TCL VOCs, TCL SVOCs, TCL Pesticides, PCB Aroclors, and TAL Metals and cyanide in the 2015 sample event. The second round samples collected at lower tide were submitted for the same constituents with the exception of PCBs. The third round samples targeted for collection at mid tide conditions were submitted for selected filtered metals to refine understanding of metals concentrations in average tidal stage conditions.

3.2 Ecological Risk Assessment and PRG Development

3.2.1 AOI 7 Middle Creek

A Screening Level Ecological Risk Assessment (SLERA), as described in Ecological Risk Assessment Guidance for Superfund (ERAGS), was completed for Middle Creek in AOI 7 and is included as Appendix N. The ecological risk assessment followed the USEPA Ecological Risk Assessment Guidance for Superfund, which is an 8-step process (USEPA, 1997). The SLERA include steps 1 and 2 of an Ecological Risk Assessment (ERA):

- Step 1 – Screening Level Problem Formulation and Ecological Effects Evaluation includes the problem formulation, preliminary ecological conceptual site model (CSM) and exposure pathways.
- Step 2 – Screening Level Exposure Estimate and Risk Calculation includes estimating exposure levels and screening for ecological risks.

The purpose of the SLERA was to determine if further evaluation is required to assess the potential risk of exposure to contaminants of potential ecological concern by ecological receptors in AOI 7 and to support the develop of CAOs for surface water and sediment in Middle Creek.

3.2.2 DVW (Honeywell/General Chemical)

As noted in Section 2, there have been a series of investigations performed on sediments at the adjacent DVW site by Honeywell and General Chemical. As part of these investigations, on behalf of Honeywell, Environ International, Inc. (Environ) developed a set of Remediation Goals (RGs) for DDx (4',4'-DDD, 4',4'-DDE, and 4',4'-DDT), arsenic and lead (Environ, 2012). These goals were developed in support of the Honeywell Interim Remedial Measures Work Plan for the Delaware River adjacent to the DVW site. Environ also developed RGs for DDx and arsenic for use in Middle Creek in addition to those developed for the Delaware River. Environ described the methods used as following the methodology submitted to the USEPA on August 15, 2011 and as approved by USEPA on August 19, 2011 (Appendix D). The DDx criteria were carbon normalized and recommended at values of 40 to 160 micrograms per gram (µg/g) organic carbon for the Delaware River and at 320 g DDx/g organic carbon in Middle Creek. Goals for arsenic were recommended at 130 to 170 mg/kg in the Delaware River and at 300 mg/kg in Middle Creek.

As part of the ongoing AOI 7 Ecological Risk Assessment activities, GHD developed an alternative RG for lead of 4,800 mg/kg for protection of fish. As noted in Section 5.5 and the SLERA, lead and other divalent metals were determined not to be bioavailable following the AVS-SEM analyses performed on samples collected in June 2016. Appendix K presents a description of the derivation of alternate lead criteria.

4. Investigation Results

Tables 4.1, 4.2, 4.4, 4.5, 4.7, 4.8, 4.10, 4.11, 4.13, 4.14, 4.16, and 4.17 present the soil data collected as part of the RFI. Tables 4.3, 4.6, 4.9, 4.12, 4.15, and 4.18 summarize the results of screening of the soil data for each of the six identified AOI 7 areas. Table 4.21 summarizes the results of screening of groundwater data for AOI 7. Table 4.22 summarizes the sediment data and Table 4.23 summarizes the surface water data collected as part of the RFI. Figure 3.1 shows all of the sample locations and Figures 4.1 to 4.10 show the results of the RFI activities. Appendix I includes laboratory reports for analyses on the soil, groundwater, sediment and surface water for the RFI. Appendix J presents the validation reports on the analyses. Stratigraphic logs for these investigations are presented in Appendix F.

4.1 Soil

Soil results are presented in Tables 4.1, 4.2, 4.4, 4.5, 4.7, 4.8, 4.10, 4.11, 4.13, 4.14, 4.16, and 4.17. The comparisons of soil data to the generic screening criteria are presented in these tables and are summarized in Tables 4.3, 4.6, 4.9, 4.12, 4.15, and 4.18. The presence of a compound at concentrations higher than screening criteria does not mean that the media necessarily poses a significant risk; it only means that further evaluation should be completed. The description of results in the following subsections notes the number of field samples, excluding duplicates, collected at each investigation area.

Soil results for lead were evaluated in relation to the SSS, as presented in Section 2.5. All other detected constituents were evaluated in the HHRA as described in Section 5.5 and Appendix O.

4.1.1 SWMU 23/24 – Old Sludge/Decant Basin

The location of the soil samples collected from the SWMU 23/24 area is shown on Figure 3.1. As discussed in Section 3, a total of 29 borings were installed to depths of 8 to 28 feet in the SWMU 23/24 area, plus an additional nine surface soil locations were investigated from 0 to 2 ft. bgs. All of these samples were analyzed for TCL VOCs, SVOCs, and TAL inorganics. Six of the locations (designated as AOI 5) were investigated as part of AOI 5 investigations adjacent to SWMU 23/24 but are included in this discussion for use in delineation.

4.1.1.1 Surface Soils

Of the 25 surface soil samples collected in the SWMU-23/24 area, several compounds exceeded the screening levels as shown in Table 4.1 and as summarized in Table 4.3. The compounds which exceeded the screening levels in the surface soils included metals, a few VOCs and a limited number of SVOCs. The soil results, except lead, that exceeded the soil screening levels were further evaluated in the HHRA. The following lead CAO exceedances were observed in soils from the 0 to 2 ft bgs interval in SWMU 23/24:

- Lead exceeded the CAO at two locations (AOI7-BH-16-010 and AOI7-BH-16-011). These samples are delineated by (AOI7-BH-16-006 and 007) to the northwest, by MW-551 to the west, by AOI7-BH-16-009 to the east, AOI7-BH-16-019 to the south and southeast, and by AOI7-BH-16-012 and 022 to the south.

Figure 4.1 depicts the surface soil samples having a concentration in excess of the lead CAO in SWMU 23/24.

4.1.1.2 Subsurface Soils

Ten subsurface soil samples were collected in the SWMU-23/24 area for full TCL/TAL analyses in 2015 and 14 additional subsurface samples for selected parameters in 2016. The constituents which exceeded the screening levels are shown in Table 4.2 and are summarized in Table 4.3. The constituents that exceeded the screening levels were similar to the surface soils and included metals and limited volatiles and semi volatiles. The soil results, except lead, that exceeded the soil screening levels were further evaluated in the HHRA. It should be noted that eight of the subsurface soil samples in SWMU 23/24 were from depths greater than 10 ft. bgs, as noted in Table 4.2, which were in saturated conditions. No significant differences were observed in the saturated soil results.

The following lead CAO exceedances were observed in soils from the 2 to 16.5 ft. bgs interval in SWMU 23/24:

- Lead exceeded the CAO at 2 locations - (AOI7-BH-15-007 at 11 to 12 ft bgs, AOI7-BH-15-008 at 8 to 10 ft bgs). Exceedances of the CAO for lead are delineated, as shown on Figure 4.2.

Figure 4.2 presents the locations where subsurface soils in the SWMU 23/24 area exceed lead CAOs.

4.1.2 SWMU 27 – Phillips Island

Twelve soil borings were advanced in the southeast corner of AOI 7 for the investigation of SMWU 27 in 2015. Soil samples were collected from depths of up to 32 ft bgs from soil borings and monitoring well installations in this area and were analyzed for TCL VOCs, SVOCs, pesticides and PCBs and TAL inorganics.

The location of soil samples in the SWMU 27 area are shown on Figure 3.1.

4.1.2.1 Surface Soils

Five soil samples were collected from surface intervals at three monitoring well locations (MW-527, MW-528, and MW-533) in the vicinity of the SWMU 27 investigation area. In addition, four surface samples were collected from borings in Phillips Island to the east in 2000. Although not part of the RFI investigation, the data from these locations is presented for delineation purposes since this area received a Release of Liability in 2004, was redeveloped and is no longer accessible. Screening of surface soil results against the screening levels is presented in Table 4.4 and summarized in Table 4.6. Limited metals and semi-volatiles exceeded the screening level criteria. The soil results, except lead, that exceeded the soil screening levels in AOI 7 were further evaluated in the HHRA.

The following CAO exceedances were noted in soils from the surface soils in SWMU 27:

- Lead exceeded the CAO at one location (MW-527 at 1 to 3 ft. bgs). The lead CAO exceedance at MW-527 is delineated on the southwest by MW-528 and on the west by MW-533, both of which had lead results less than the CAOs. Data available from the Phillips Island Closure Report (URS, 2005) shows that the lead CAO exceedances are bounded by 0 to 2 ft. bgs samples to the west, east and northeast, at locations MW-145, B-PH1, B-PH2, and B-PH3.

Figure 4.10A shows the location of shallow soil samples in the SWMU 27 area that exceed the lead CAOs.

4.1.2.2 Subsurface Soils

Eighteen soil samples were collected from subsurface intervals at ten of the soil borings and at the four monitoring wells in the area in 2015. Screening of subsurface soil results against the screening levels is presented in Table 4.5 and summarized in Table 4.6. Limited metals, benzene and semi-volatiles exceeded the screening levels. The soil results that exceeded the soil screening levels were further evaluated in the HHRA. Thirteen of the subsurface soil samples in SWMU 27 were collected from depths greater than 10 ft. bgs, in saturated conditions, as is noted in Table 4.5. Arsenic concentrations were slightly higher in some of the saturated samples than the non-saturated samples.

None of the subsurface soil samples exceeded the CAO for lead in SWMU 27:

Figure 4.4 depicts the locations of subsurface samples in the SWMU 27 area.

4.1.3 Middle Creek Area

Seven surface soil samples were collected at locations where monitoring wells were installed along Middle Creek during the period of the RFI. Data from four samples at the Ethylene Complex Warehouse (ECWH_01 through 4) collected August 18, 2015 were also used to assist in delineation. The location of these soil samples is shown on Figure 3.1.

4.1.3.1 Surface Soils

Soil samples were generally collected from the 0- to 2-foot interval (although some were from 1.5 to 3.5 ft bgs if concrete or gravel was present) for shallow soil characterization immediately adjacent to the Middle Creek Area. Screening of soil results against the screening levels is presented in Table 4.7 and summarized in Table 4.9. Limited metals, pesticides and semi-volatiles exceeded the screening level criteria. The soil results that exceeded the soil screening levels were further evaluated in the HHRA.

No results in the surface soils at the Middle Creek Area exceeded the lead CAO as shown on Figure 4.5.

4.1.3.2 Subsurface Soils

Eight subsurface soil samples were collected in the Middle Creek Area from intervals between 2 and 12.5 ft. bgs. Each sample was analyzed for TCL VOCs, SVOCs, pesticides, PCBs and TAL inorganics. Screening of soil results against the screening levels is presented in Table 4.8 and summarized in Table 4.9. Limited metals and semi-volatiles exceeded the screening level criteria. The soil results that exceeded the soil screening levels were further evaluated in the HHRA. Three of the subsurface soil samples in the Middle Creek Area were collected from depths greater than 10 ft. bgs, where saturated conditions are encountered, as noted in Table 4.9.

CAO exceedances were observed in subsurface soils in Middle Creek Area for:

- Lead exceeded the CAO at one location - (MW-539 at 6.5 to 8 ft. bgs). This location is delineated as shown on Figure 4.10B.

Figure 4.10B shows the location of the CAO exceedance for subsurface soils in the Middle Creek Area.

4.1.4 Area South of Middle Creek

Soil samples were collected at 7 monitoring well locations in this area during the RFI. The monitoring well locations included four locations near the river (MW-529, MW-530, MW-531, and MW-532), one location approximately 250 feet north of MW-530 (MW-534) and two in the central Ethylene Complex (MW-561 and MW-562). Data from four samples at the Ethylene Complex Warehouse (ECWH_01 through 4) collected August 18, 2015 were also used to assist in delineation. The location of these soil samples is shown on Figure 3.1. Soil samples were sampled for TCL VOCs and SVOCs, pesticides and TAL inorganics.

4.1.4.1 Surface Soils

Soil samples were generally collected from the 0 to 2-foot interval (although some were collected from 1 to 3 ft bgs if concrete or gravel was present 0 to 1 ft bgs) for shallow soil characterization. Screening of soil results against the screening levels is presented in Table 4.10 and summarized in Table 4.12. A limited number of metals and semi-volatiles exceeded the screening levels. The soil results that exceeded the soil screening levels were further evaluated in the HHRA.

No lead CAO exceedances were observed in soils from the surface soils in the Area South of Middle Creek, as shown on Figure 4.7.

4.1.4.2 Subsurface Soils (2 to 29.5 ft. bgs)

Sixteen subsurface soil samples were collected from the seven monitoring well installation boreholes in the area south of Middle Creek during the RFI. Screening of soil results against screening levels is presented in Table 4.11 and summarized in Table 4.12. Aroclor 1260 and a limited number of metals and semi-volatiles exceeded the screening levels. The soil results that exceeded the soil screening levels were further evaluated in the HHRA. Eight of the subsurface soil samples in the Area South of Middle Creek were collected from depths greater than 10 ft. bgs, which where saturated conditions are encountered, as noted in Table 4.11. Arsenic concentrations were slightly higher in the some of the saturated samples than the non-saturated samples.

The following CAO exceedances were noted for subsurface soils in the Area South of Middle Creek:

- Lead exceeded the CAO in one location (MW-562 at 8 to 9 ft. bgs). The lead CAO exceedance is delineated in all directions as shown on Figure 4.8.

Figure 4.8 shows the location of CAO exceedances for subsurface soils in the Area South of Middle Creek.

4.1.5 Soils West of Middle Creek

Four soil borings were advanced and sampled for the installation of four monitoring wells (MW-557, MW-558, MW-559, MW-560) on the west side of Middle Creek and one to the northwest of the bend in Middle Creek (MW-551). All five of these borings and wells were immediately adjacent to the property line with the DVW facility and represent background or off-site impacts to AOI 7.

4.1.5.1 Surface Soils

Five soil samples were collected from surface intervals at each of the monitoring well locations. Each of these samples was analyzed for full TCL/TAL analyses. Screening of soil results against the screening levels is presented in Table 4.13 and summarized in Table 4.15. Metals, SVOCs, a limited number of volatile organics and a number of pesticides exceeded the screening levels. The soil results that exceeded the soil screening levels were further evaluated in the HHRA.

CAO exceedances were observed in soils from the surface soils in the Area West of Middle Creek as follows:

- Lead exceeded the CAO at one location (MW-560). The lead exceedances are delineated to the north and east but were not delineated to the west since that is the DVW property or to the south due to the Delaware River as shown on Figure 4.9.

Figure 4.9 shows the location of shallow soil samples in the Area West of Middle Creek that exceed CAOs.

4.1.5.2 Subsurface Soils

Five subsurface soil samples were collected, one from each of the five monitoring well installed west of Middle Creek during the RFI. Each of these samples was analyzed for full TCL/TAL analyses. Screening of soil results against screening levels is presented in Table 4.14 and summarized in Table 4.15. Limited metals and semi-volatile organics and a number of pesticides exceeded the screening level criteria. The soil results that exceeded the soil screening levels were further evaluated in the HHRA. One of the subsurface soil samples in the Area West of Middle Creek was collected from depths greater than 10 ft. bgs, where saturated conditions are encountered, as noted in Table 4.14.

The following CAO exceedances were noted for subsurface soils West of Middle Creek:

- Lead exceeded the CAOs at one location (MW-560 at 2 to 5 ft bgs). The lead CAO exceedances are delineated to the north and east as shown by Figure 4.10. The CAO exceedances were not delineated to the West since that is the DVW property or to the South due to the Delaware River.

Figure 4.10 shows the locations where subsurface soil in the Area West of Middle Creek that exceeded CAOs.

4.1.6 17 Plant Area

Seven soil borings were installed in a grid pattern in the former 17 Plant Area north of the railroad tracks and south of the northern above ground storage tank area in the northern end of AOI 7. Samples were analyzed for full TCL/TAL analyses.

4.1.6.1 Surface Soils

Screening of the seven surface soil results against the screening levels is presented in Table 4.16 and summarized in Table 4.18. Only arsenic and benzo(a)pyrene exceeded screening levels criteria in the surface soils in the 17 Plant Area. The soil results that exceeded the soil screening levels were further evaluated in the HHRA.

None of the soil analytical results in the 17 Plant Area surface soils exceeded the lead CAO.

4.1.6.2 Subsurface Soils

Screening of the seven soil results against the screening levels is presented in Table 4.17 and summarized in Table 4.18. Arsenic, benzo(a)pyrene and benzene were the only constituents that exceeded the screening levels. The soil results that exceeded the soil screening levels were further evaluated in the HHRA.

None of the subsurface soils had concentrations that exceeded the lead CAO in the 17 Plant Area.

4.2 Groundwater

4.2.1 Groundwater Elevations and Gradients

Groundwater level measurements were collected during sampling events in September 20-15, January 2016 and June/July 2016. The groundwater elevations from all three events are summarized in Table 4.19. The calculated elevations are presented on Figure 2.6 for the MHIC-wide groundwater elevations in 2016 and on Figure 4.11 for the groundwater level measurements in AOI 7 during the RFI. In general, groundwater flow is south toward the Delaware River, except in the immediate vicinity of Middle Creek which is a localized discharge area for shallow groundwater. Gradients north of Middle Creek are approximately 0.0075 towards Middle Creek. Gradients south of Middle Creek in areas of groundwater flow towards Middle Creek range from 0.008 to 0.04. Gradients south of Middle Creek near the Delaware River range from 0.008 to 0.01.

The two screened intervals available at the eight well clusters adjacent to the Delaware River allow the calculation of vertical gradients. Table 4.20 presents three gaging events. Vertical gradient were calculated by the difference in corrected groundwater elevations between the upper and lower screens at a cluster and dividing that by the difference in the elevation of the midpoints of the screens. The results show a trend of negative (upward discharge) gradients on the eastern side of the riverfront in the vicinity of MW-527, MW-528, and MW-529, and positive (downward discharge) in the western portion of the river front at MW-530, MW-531, and MW-532. The trend becomes stronger moving from the center; that is more upward moving east and more downward moving west. It should be noted that the fluctuations in groundwater elevations resulting from tidal changes may impact the comparison of well clusters if not measured close in time to one another and these potential impacts were accounted for during the RFI activities.

4.2.1.1 Tidal Influence

As noted in Section 3.1.2.2, a tidal study was completed at 15 monitoring wells and one stilling well during the RFI. The locations situated closer to the riverfront show increased tidal influence and connectivity to the river, as shown in the graphed transducer data presented in Appendix G. The groundwater elevation data collected from October 1 to October 10, 2015, from two monitoring well locations in AOI 7 (MW-533U and MW-528U), as well as the Delaware River and the stilling well are shown on Figure 4.12.

The average tidal amplitude is approximately 6 feet in the Delaware River (as measured at the stilling well) and 1 to 2.7 feet at the monitoring wells located along the riverfront. Minimal tidal effects (stage change approximately 0.1 to 0.15 feet) were observed at the locations approximately 250 to 300 feet from the riverfront. The wells displayed an identifiable sinusoidal pattern in their water levels (reflecting tidal influence) throughout the study, with the exception of MW-532U, MW-36, MW-214, MW-29, and MW-501. In portions of the tidal study, a limited observed response to changing river levels in several wells behind the bulkhead on the river (MW-29 in AOI-3, MW-35, and MW-141 in AOI 6, and MW-532 in AOI 7). This limited response is expected to result from reduced hydraulic communication due to the presence of the bulkheads and low permeability fill materials. The data collected during the study is included as Appendix G.

During groundwater sampling activities, significant changes were also noted in the monitoring wells located immediately adjacent to Middle Creek, as tidal changes occurred. Middle Creek tidal fluctuations were observed to be several feet in amplitude and occurring quite rapidly as would be expected in a small channel adjacent to a large tidal water body.

4.2.1.2 Slug Test Results

AQTESOLV was used to calculate hydraulic conductivity from the aquifer test data, using the Bouwer-Rice method. This analysis calculates hydraulic conductivity by considering the change of height of water in the well casing due to a slug displacing water.

The hydraulic conductivities calculated from the aquifer test were: MW-532 - 1.7×10^{-4} cm/s, MW-36 - 1.7×10^{-4} cm/s, MW-21 - 4.4×10^{-5} cm/s, and MW-320 - 1.1×10^{-4} cm/s. These results suggest that the permeability of the fill is within the expected range of K for sandy silts and are consistent with other estimates of hydraulic conductivity at the Facility. Appendix M presents the details of the slug test analyses.

4.2.2 Groundwater Flow

Groundwater resides in fill and underlying natural sediments under water table conditions throughout AOI 7. An average saturated thickness of 15 to 50 feet is expected in AOI 7 thickening toward the river. Groundwater flow is towards the river or toward the upper reach of Middle Creek, with the exception of the south side of Middle Creek where it is locally directed northerly toward the creek. The tidal impacts on flow direction are expected to be limited, resulting in a filling of the banks immediately adjacent to the tidal water during high tide and reducing the gradient to the surface water or steepening the gradient during low tide. As noted in the tidal study, these impacts will be minimal at distance from the surface water (MW-533 experienced an amplitude of 0.1 to 0.15 ft. bgs at 300 feet from the river).

Using the hydraulic conductivity estimated from the slug test on MW-532U (0.48 ft./day) and the gradients measured from the potentiometric surface, and an assumed porosity of 0.3 for sandy silts a groundwater seepage velocity can be calculated:

Seepage Velocity (ft./d) = [hydraulic conductivity (ft./d) x gradient (ft./ft.]/porosity

= [0.48 ft./day x 0.01 ft./ft.]/0.3 = 0.016 ft./d

= 0.016 ft./day x 365 day/year = 5.84 ft./yr

With a river frontage of 1,400 feet and an assumed average saturated thickness of 23 feet, this will provide a groundwater discharge of 515 cubic feet per day or 3,850 gallons per day or 2.7 gallons per minute along the AOI 7 river front.

4.2.3 Groundwater Results

A total of 44 monitoring wells were sampled during the RFI activities, including 21 in September 2015 during the initial sampling event of newly installed wells, 6 in January 2016 after wells were installed on the western boundary area and a total of 42 in June to July 2016 AOI 7. A total of 76 groundwater samples and one seep sample were collected from AOI 7 locations during the RFI.

Concentrations in monitoring wells exceeded groundwater screening levels (MCLs) and the CAOs as shown in Table 4.21 and summarized in Tables 4.3, 4.6, 4.9, 4.12, 4.15, and 4.18 for each of the areas discussed above for the soil results. The compounds that exceeded the screening levels included limited metals, semi-volatiles and volatiles as noted in the referenced tables. The evaluation of the groundwater data in relation to the CAOs is discussed in Section 4.2.3.7.

4.2.3.1 SWMU 23/24 – Old Sludge/Decant Basins

The locations of the groundwater wells adjacent to SWMU 23/24 are shown on Figure 3.1. Monitoring wells MW-182, MW-184, and MW-187 are the closest wells to the former basins and are on the downgradient side of the units, discharging into Middle Creek. Each of these wells was sampled once during the June/July 2016 sampling event. Table 4.3 presents a summary of groundwater results against the screening levels (MCLs). Of the three samples collected, the MCLs were exceeded twice for arsenic, once for lead and twice for benzo(a)pyrene.

4.2.3.2 SWMU 27 – Phillips Island

The locations of the six groundwater wells in SWMU 27 are shown on Figure 3.1. Cluster monitoring wells MW-527U and L, MW-528U and L, and MW-533U and L are located near the river front and set north of the riverfront wells by 250 to 300 feet, respectively. Each of these wells was sampled once in September 2015 and once during the June/July 2016 sampling event. Table 4.6 presents a summary of the screening of the groundwater results from the wells against the screening levels, the interim screening levels (for water discharging into the Delaware River) and the CAOs based on groundwater discharging into the Delaware River. Of the twelve samples collected, the groundwater screening levels (MCLs) were exceeded in nine samples for dissolved arsenic and one sample for bis(2-ethylhexyl)phthalate.

4.2.3.3 Middle Creek Area

The locations of the groundwater wells along Middle Creek are shown on Figure 3.1. Monitoring wells MW-536, MW-537, MW-538, MW-539, MW-132, MW-293, and MW-509 are all on the east or south side of Middle Creek. MW-540, MW-541, MW-182, MW-184, MW-187, and MW-277 are on the north side of Middle Creek. All of these wells flow into Middle Creek. The monitoring wells installed in the RFI (MW-536 and MW-541) were sampled in September 2015. All of the wells (except MW-536 which could not be found) were sampled a second time in the June/July 2016 sampling event. Monitoring wells MW-132, MW-182, MW-184, MW-187, and 277 all had at least one sample collected from beneath LNAPL.

Table 4.9 presents a summary of the screening of the groundwater results from the wells against the screening levels. Of the 19 samples collected, the groundwater screening levels (MCLs) were exceeded for dissolved metals (antimony, arsenic, lead, and selenium), benzo(a)pyrene, bis(2-ethylhexyl)phthalate, benzene, and chlorobenzene.

In addition to the groundwater data collected from the monitoring wells, a seep sample was collected from a location on the east bank of Middle Creek adjacent to surface water station SW-002. As shown in Table 4.21, this sample exceeded the groundwater screening values (MCLs) for dissolved DDE, DDD, DDT, arsenic, barium, and selenium as well as for benzene.

The arsenic, DDD, and DDE data are indicative of background conditions which reflect that the AOI-7 media are impacted from historic off-facility discharges from DVW.

4.2.3.4 Area South of Middle Creek

The locations of the groundwater wells in the area between Middle Creek and the Delaware River are shown on Figure 3.1. The monitoring wells in the Area South of Middle Creek include MW-534L, MW-534U, MW-532L, MW532U, MW-531L, MW-531U, MW-530L, MW-530U, MW-529L, MW-529U, MW-56, MW-55, MW-53, MW-561, and MW-57. The following monitoring wells had at least one sample collected from below LNAPL; MW-532U, MW-534L, MW-534U, MW-53, MW-56, MW-47, and MW-562.

Table 4.12 presents a summary of the screening of the groundwater results from the wells against the screening levels (MCLs). Of the 26 samples collected, the screening levels (MCLs) were exceeded for dissolved metals (antimony, arsenic, cadmium, lead, and selenium), benzene, benzo(a)pyrene, pentachlorophenol, and gamma-BHC.

4.2.3.5 Area West of Middle Creek

Figure 3.1 shows the locations of the groundwater wells west of Middle Creek which include seven wells MW-551 MW-47, MW-48, MW-557, MW-558, MW-559, and MW-560, all of which flow into Middle Creek with the exception of MW-560. MW- 558 had at least one sample collected from beneath LNAPL. Each of the five wells installed for the RFI (MW-551, MW-557 though MW-560) were sampled after their initial installation; all seven of the wells were sampled once during the June/July 2016 sampling event. Table 4.15 presents a summary of the screening of the groundwater results from the wells against the screening levels.

Of the 12 samples collected, the screening levels (MCLs) were exceeded for a number of dissolved metals, including arsenic, cadmium, copper, lead, benzo(a)pyrene, benzene, and chlorobenzene.

4.2.3.6 17 Plant Area

The locations of the groundwater well adjacent to the 17 Plant Area is shown on Figure 3.1. Monitoring wells MW-552 was the only well sampled in this area during the RFI. This well was sampled once during the June/July 2016 sampling event. Table 4.18 presents a summary of the screening of the groundwater results. No screening levels were exceeded for the sample collected from MW-552.

4.2.3.7 Sitewide Groundwater Discharge to Middle Creek and Delaware River

In Appendix M, the relationship between groundwater seepage from the facility and surface water flow in the Delaware River was modeled using CorMix, resulting in the recommendation to use a groundwater to surface water mixing value for a conservative evaluation of surface water quality standards (DRBC criteria as described in 2.5.2.5.4) to establish the groundwater CAOs. As discussed in Appendix M, the results of the CorMix modeling resulted in the identification of a 10,000:1 ratio for use in comparison of groundwater to surface water values based on the predicted mixing of flows in the Delaware River. In an effort to have a conservative contingency or trigger concentration, a 1000:1 groundwater to surface water ratio, was also identified in the analysis. Groundwater values within 300 feet of the Delaware River and the wells immediately bordering Middle Creek were compared to both the 10,000:1 to 1,000:1 groundwater to surface water mixing values, as summarized on Tables 4.21 and 4.24. All of the groundwater results were below both of these values , with exception of results from MW-531L, MW-532U/L, Seep at Lower Creek, MW-56, MW-557, MW-558, MW-559, and MW-560 for arsenic, DDD, DDT, DDE, alpha BHC, beta BHC, Aldrin, and/or heptachlor epoxide. All of these wells are located in the area influenced by historical off-site impacts from the Honeywell and General Chemical property and do not represent compounds of concern for AOI 7. None of the other parameters in groundwater exceeded CAOs.

4.2.4 LNAPL Occurrence

Measurements collected during the RFI detected LNAPL in MW-55, MW-56, MW-532 U, MW-534U, MW-534L, MW-558, MW-132, MW-182, MW-184, MW-187, MW-277, MW-562, as summarized in Table 4.13. LNAPL thickness varied but ranged from a sheen to 7.19 feet in MW-534U. The observed LNAPL were relatively stable in the majority of the monitoring wells (MW-56, MW-534L, and MW-561) but did vary in MW-534U and MW-55, possibly in response to tidal effects on the underlying groundwater surface. The following summarizes the LNAPL observations made during the RFI:

- During the October 2015 event (Table 4.19), 23 wells were gauged in the shallow and deep zones. LNAPL was detected in 2 wells with a maximum thickness of 7.19 feet at well MW-534U.
- During the June/July 2016 event (Table 4.19), 42 wells were gauged in the shallow and deep zones. LNAPL was detected in twelve wells, five in the vicinity of the Middle Creek Remediation System (list out wells), one at the western boundary north of Middle Creek (MW-47), one on the west side of Middle Creek (MW-558) and five in the southern portion of AOI 7 (list out wells). LNAPL ranged from trace accumulations to a maximum thickness of 10.85 feet (in MW-55).

LNAPL testing was completed to characterize the LNAPL in AOI 7 on July 15, 2011 by Langan (Langan, 2012). LNAPL from monitoring well MW-54 was collected and submitted to Lancaster Laboratories, Inc. (LLI) for analysis. LLI completed gas chromatograph analyses of the samples. LNAPL characterization data included product type, density, proportions of product, weathering, and similarities to other samples. LLI characterized the sample from MW-54 as being slightly weathered lube oil. LNAPL in the vicinity of Middle Creek was identified a residual oil. A 1995 investigation revealed LNAPL similar to weathered No. 2 fuel oil near MW-83, MW-45, and in the area north of Middle Creek (GES, 1995). LNAPL characterization data was collected from monitoring well MW-132 and was identified to be slightly weathered lube oil. Stantec has reevaluated the NAPL designations at the MHIC, and the NAPL in AOI 7 has been identified as a heavy distillate.

Although the results from LNAPL gauging in the RFI generally correlate with the pattern of LNAPL from prior events, new detections were made in MW-534U and MW-534L (which are within the boundary of LNAPL mapped in 2015 by Evergreen), a trace product observation in MW-531L (which is expected to relate to the LNAPL plume at MW-54, MW-55, and MW-534) and the 0.02 ft. thick LNAPL observation in MW-558 on the west side of Middle Creek. LNAPL at MW-531L is delineated by the sheet piling wall at the Delaware River. LNAPL in MW-558 is delineated to the north and south by MW-557 and MW-559, respectively. LNAPL at AOI 7 has been delineated to the north northwest of well MW-47 by the installation of MW-551, where LNAPL has not been observed at the western property line.

4.3 Sediment

As noted in Section 3, sediments within Middle Creek were sampled in two events, one in August 2015 and one in June 2016. The initial sediment characterization included full TCL/TAL analyses and PCBs. The second sampling event in June 2016 included supplemental data on PAHs and metals to refine ecological risk assessment, particularly for availability of divalent metals and a full assessment of PAH narcosis. Confirmatory sampling was also performed for PCBs in the upper reach of Middle Creek.

The comparison of sediment data to the screening levels are summarized in Table 4.22. The screening levels for sediment are the BTAG values and they were used to identify Constituents of Potential Ecological Concern (COPECs) as a focus for further risk assessment. The SLERA for AOI 7 Marcus Hook Industrial Complex presents a detailed analysis of surface water and sediment data from Middle Creek. Some of the conclusions of the SLERA are reflected in this section. A summary of the findings of the SLERA are presented in Section 5.

4.3.1 Metals

- Surface sediment data (0 to 0.5 feet) show the presence of metals (antimony, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver and zinc) were present at concentrations above the screening levels throughout Middle Creek. In some cases there is a pattern to the distribution of the metals, such as arsenic, mercury, and selenium, where the highest concentrations are in the most downstream stations (SED-001 and SED-002) near the mouth of the creek, or in the mid upstream section of the creek, such as lead, copper and cadmium, where the highest concentrations were at SED-007 or SED-008. Other metals, such as chromium, and silver show no clear pattern of either kind and are at generally consistent concentrations throughout Middle Creek.
- Deeper sediment samples (1.5 to 2.0 or 2.0 to 2.5 feet) had patterns very similar to the surface sediments for metals as discussed above. Where the patterns indicate higher concentrations in the downstream stations (i.e., arsenic), a background (non-facility source) condition is indicated. Sources originating from the MHIC facility would be expected to display higher concentrations in upstream locations indicating a source on the facility. Off-facility sources, especially for constituents known to have been released at adjacent industrial operations and present in the river, are expected to show higher concentrations nearer to that source and in the downstream end of Middle Creek.
- Further refinement of the assessment of metals concentrations in Middle Creek sediments was provided by evaluation of the AVS-SEM balance for divalent metals and acid volatile sulfides. As described in the SLERA, the AVS-SEM balances for all ten sediment stations were less than 130 μmol/g of excess divalent metals over sulfide concentrations, meaning that divalent metals (cadmium, chromium, copper, lead, mercury, nickel and zinc) are not sufficiently bioavailable to provide toxicity to benthos in the sediment of Middle Creek. A more detailed discussion of this evaluation is provided in the SLERA in Appendix N.
- The site-specific preliminary remediation goal for arsenic in sediments developed by Environ for Middle Creek was exceeded by sediments at only two stations, SED-001 and SED-002 at the mouth of the creek.

Figure 4.14 presents distribution trends for arsenic in Middle Creek sediments.

4.3.2 Semi-Volatiles

- Surface sediment data (0 to 0.5 feet) show the presence of semi-volatile organic compounds generally at concentrations above BTAG screening levels throughout Middle Creek. No pattern of distribution was evident from the collected data.
- Deeper sediment samples (1.5 to 2.0 or 2.0 to 2.5 feet) had patterns generally similar to the surface sediments for metals as discussed above. In order to assess the potential for PAH toxicity, a full analysis of 34 PAH compounds (USEPA, 2003b) was performed for the 0- to 0.5-foot interval for each of the ten sediment stations in June 2016. The results of the PAH analyses were partitioned to aqueous values using organic carbon data for each sample. The

partitioned concentrations were then compared to reference toxicity concentrations for each compound and the ratios of each compound to reference value were summed across all PAHs. Where a hazard quotient of 1 or less results there is no toxicity indicated from PAHs. All hazard quotients for the ten stations were significantly less than 1, demonstrating no narcotic toxicity from PAHs. A more detailed discussion of this analysis is provided in the SLERA.

4.3.3 Pesticides

- Pesticides were detected in Middle Creek sediments at concentrations above BTAG screening levels. DDD, DDE, alpha-BHC, beta-BHC, gamma-BHC, dieldrin, and endosulfan I were each reported to exceed the screening criteria in at least one sample. DDD and DDE were the most abundant of the pesticides with concentrations an order of magnitude or more above the other pesticides. The pattern of pesticide concentrations in sediments shows a declining trend from downstream to upstream, with the highest concentrations at the most downstream limit of Middle Creek at SED-001 and SED-002 and the lowest concentrations at SED-009 and SED-010.
- The pattern of pesticide concentrations in deeper sediments (1.5 to 2.0 or 2.0 to 2.5 feet) were generally similar to those in the surface sediments in terms of relative concentrations among the sediments and declining concentrations upstream from the mouth. Where the patterns indicate higher concentrations in the downstream stations, a background (non-facility source) condition is indicated.
- The site-specific preliminary remediation goal for DDx in sediments developed by Environ for Middle Creek was exceeded by sediments at only two stations, SED-001 and SED-002 at the mouth of the creek. Figure 4.14 presents the distribution trend of DDx in sediment along the length of Middle Creek.

4.3.4 Volatile Organics

- Volatile organic compounds were detected in surface sediments sporadically along the length of Middle Creek in the 2015 sampling event. Chlorobenzene most commonly exceeded its BTAG screening value in surface sediment. Stations SED-002 and SED-005 had the highest detections in the shallow sediment samples.
- Deeper sediment samples also detected VOCs throughout Middle Creek. Chlorobenzene was the most commonly detected volatile organic above screening levels, with highest detections at SED-002, SED-005 and SED-006. Cumene also was detected in sediments at SED-009 and SED-010 above screening levels.

4.3.5 PCBs

PCB results were all at non-detected or very low concentrations with the exception of a field duplicate of the 0- to 0.5-foot sample from SED-007 in 2015. The parent sample had a reported concentration of 0.022 mg/kg of Aroclor 1260; however, the field duplicate had a result of 8.5 mg/kg. Six of the upstream stations (SED-005, SED-006, SED-007, SED-008, SED-009, and SED-010) were resampled for PCBs in June 2016. All six results for Aroclor 1260 were non-detect, verifying that the duplicate result was an anomaly and not a reliable measurement for PCBs in Middle Creek.

4.4 Surface Water

Surface water samples were collected in Middle Creek during three events (in September 2015, and in June/July 2016) for full TCL/TAL analytes. As discussed in Section 3.1.5, the June 2016 event was timed to capture conditions at a lower tidal stage. As also discussed in Section 3.1.5, a partial sampling event in September 2016 was performed to collect additional data on metals at representative locations at an 'average' tidal stage.

The comparison of surface water data to the screening levels are summarized in Table 4.25. The presence of surface water with constituent concentrations higher than these screening levels does not mean that the media necessarily poses a significant risk; it only means that it should be further evaluated in an ecological risk assessment.

Table 4.25 presents the results of the surface water sample analyses in comparison to the screening levels. The results of the surface water sampling are summarized in the following:

- One sample exceeded the screening level for lead at SW-008 in the September 2016 sample. None of the other three samples at this station had an exceedance of the screening level for lead. It should be noted that the DRBC criteria are designed to assess surface water conditions over a period of time. The average lead concentration for the 30 samples collected in Middle Creek during the RFI are below the DRBC criteria. As applied to the body of data in Middle Creek from the RFI, the surface water quality meets standards for metals.
- Four PAHs also had one exceedance at one station of the screening levels: benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene, all at SW-010 in June 2016. The results were the only detections of these constituents of the twenty one analyses of Middle Creek surface water. The average concentrations of these four PAHs for the Middle Creek surface water are below the DRBC criteria (screening levels) for each of the four constituents indicating that that the criteria are met under average conditions.
- The remaining and predominant constituents that exceeded DRBC criteria are pesticides, which originate from releases off-Site (background). DDD exceeded criteria in nine station samples in 2015 and 2016. DDE and DDT likewise exceeded in five stations in the 2015 sampling and four and six samples respectively in 2016. This pattern was similar for alpha-BHC, which exceeded screening levels at all ten stations in both events; beta-BHC exceeded the criteria at four stations in 2015 and all ten during the low tide sampling in 2016. The pattern of higher concentrations of pesticides may indicate off-site impacts during the filling activities as summarized in Section 2.3 and 2.4.

4.4.1 Mixing Model

The first step in the surface water mixing zone modelling study involved determining the most applicable modelling software for the site-specific groundwater-to-surface water interface. Due to the tidal nature of the Delaware River as documented in *Observations of Tidal Flow in the Delaware River, E.G. Miller, Geological Survey Water-Supply Paper 1586-C* (Paper 1586-C) and site-specific tidal observations the CorMix modelling software was selected, because it is able to consider mixing behavior and plume geometry that is suited for the tidal conditions of the Delaware River. The CorMix model applies a computational algorithm that considers the mixing zone volume variable dependent on the distance from the original site-specific groundwater-to-surface water interface. Additionally, CorMix allows for tidal information to be included so that the model can accurately estimate the reduced (conservative) dilution due to tidal re-entrainment. Input parameters for the CorMix model include groundwater flux into the receiving surface water body, surface water flux at the point of groundwater discharge, and the dimensions of the receiving surface water body. Appendix G presents a memorandum on the input parameters and model set up used for the mixing zone calculations.

Groundwater gradients were evaluated at four sections of the MHIC facility where slug tests were performed to measure hydraulic conductivity of the fill materials. The resulting gradients and conductivities were multiplied and used with the length of river bank to yield a groundwater seepage flux. Based on that evaluation, a conservation flux estimate of 0.02 cubic feet per second (ft^3/sec) was applied along the entire length of the shoreline, even if a bulkhead was present. The entire length of the groundwater-to-surface water interface (shoreline of the facility) was then evaluated by varying the diffuser length in the model.

Based on the examination of the local bathymetry map listed in Paper 1586-C, the local river depth adjacent to the site was set at 12 feet below the water surface and the local river depth at the diffuser (seep) was set at 9 feet below the water surface. Additionally, the mean ambient receiver velocities (nearshore Delaware River) were based on the tidal discharge and velocity observations and those average water velocities (2 to 3 ft/sec) were extrapolated to nearshore conditions. It should be noted that the depth of the river is often greater along the MHIC river front due to the maintenance of docking berths for shipping (up to 40 feet or more in locations), so the selected depths represented conservative assumptions in the modeling.

The results from the CorMix model vary depending on input data; so a sensitivity analysis was complete to evaluate the model inputs. The sensitivity analysis indicated that the ambient (receiver) water velocity was the only significant variable with physical meaning. This study used the oscillating tidal method, which gave results essentially identical to "steady-state" (single ambient velocity) modeling at a point in the tidal cycle. The lowest dilutions were calculated for at-slack1 conditions and highest dilutions were calculated for at-peak (highest velocity) conditions. The outputs from the model were used to conservatively calculate the CAOs for groundwater discharging to the Delaware River.

5. Site Conceptual Model

The following section presents the Site Conceptual Model for AOI 7 based on the results of the RFI activities.

5.1 Description and Site Use

The MHIC is located on the north bank of the Delaware River spanning between Delaware and Pennsylvania The facility frontage extends approximately 4,800 feet along the northern banks of the Delaware River. The facility, which is located on industrial property, covers approximately 585 acres of land with access restricted by fencing and security measures. Current operation of the facility

(24 hours per day) includes the processing and storage of light hydrocarbon products plus support facilities.

AOI 7 is located in Delaware and consists of approximately 50 acres of land bounded on the southeast by the Delaware River, the southwest by a property boundary with Delaware Valley Works (DVW), also referred to as General Chemical and Honeywell) and by the Pennsylvania-Delaware state line/AOI 5 on the northeast. Middle Creek runs through AOI 7.

Potential receptors for soil are industrial workers and construction workers at the AOI 7. No groundwater is used or is expected to be used at the facility. The highest and best use for groundwater is recharge to surface water.

5.2 Geology and Hydrogeology

The geologic framework underlying the facility can be grouped into three general units. The uppermost unit is anthropogenic fill, which generally covers the entire surface of the facility to varying depths. Underlying the fill is recent alluvium consisting primarily of silty clay which may have been deposited in estuarine environments of the Delaware River or a tributary, such as Middle Creek. The third unit includes unconsolidated sands and gravels with silt and clay, overlies the crystalline bedrock. Borings completed as part of the RFI confirmed fill thickness north of Middle Creek to be 12 to 15 feet and fill thickness along the current river bulkhead to be 25 to 30 feet.

Topography in AOI 7 was naturally low lying coastal plain prior to development in the early 20th century. Significant filling occurred in AOI until the 1950s/1960s. Middle Creek was re-routed several times from the late 1800s to the 1950s. Industrial activity at the DVW was ongoing to the west of AOI 7 prior to and during the filling and development of AOI 7. Filling activity at DVW was noticeable adjacent to the AOI 7 boundary as early as 1937, and bermed areas that appear to have received siltation are apparent in the 1950s. A large pond and an apparent disposal pile appear just west of AOI 7 on the DVW property in the 1965 historical photograph. Historical photos show the movement of materials from the adjacent DVW property to locations within the current AOI 7 boundary.

Groundwater elevations in AOI 7 generally range from 5 to 15 feet below grade in the fill material. Groundwater generally flows southeast toward the Delaware River or locally towards Middle Creek. Groundwater is locally influenced by pumping associated with fluids recovery by the Middle Creek remediation system. In the downstream section of the creek, groundwater flow appears to be less influenced by Middle Creek due to the proximity of this area to the Delaware River. Groundwater within close proximity to the Delaware River is influenced by the existing bulkhead and the tidally-influenced river stage.

5.3 Potential Sources Areas

The two SWMU areas in AOI 7, SWMU 23/24 and SWMU 27, are potential source areas within AOI 7. In addition to these areas, limited areas of LNAPL were identified within AOI 7 that are potential source areas. Another potential source of contamination for AOI 7 is background, or historic off-facility sources. There are widespread concentrations of DDx and arsenic in soil and sediment at the site that are typically above screening criteria. These concentrations are not believed to be associated with any known or potential releases from the facility. There are no known current or past uses of DDx or arsenic in the site-related (refining) activities. Many of the DDx and arsenic concentrations are at the downgradient portion of the site, along the Delaware River, and adjacent to the DVW, the site of a former pesticide manufacturing facility. DDx and arsenic are present in the Delaware River adjacent to the former pesticide manufacturing facility. Because the flow of the Delaware River adjacent to the site is tidally influenced, transport of sediments containing DDx and arsenic from those former operations are believed to have been transported upstream. As shown on Figure 5.1, the pattern of DDx contamination found in Delaware River and Middle Creek sediments indicates a historic depositional source from off facility. Figure 5.2 presents the same information for arsenic. Therefore, DDx and arsenic concentrations in soil and sediment at AOI 7 are believed to be from non-site-related sources and are considered anthropogenic background concentrations.

5.4 Nature and Extent of Impacts

Soil, groundwater, surface water and sediment results have been screened against the screening levels discussed in Section 4. The following subsections summarize the extent of these impacts in relation to the Corrective Action Objectives.

5.4.1 AOI 7 Related Constituents

There are very few surface soil samples that exceed the lead CAO within AOI 7. The CAO exceedances are limited to two locations in the SWMU 23/24 area, one in SWMU 27, and one (MW-560) on the west side of Middle Creek. The samples in SWMU 23/24 and SWMU 27 are well delineated in all directions. The exceedance at MW-560 on the west side of Middle Creek is clearly not related to facility impacts in view of the very low lying position of this sample, and its proximity to contamination sources in the adjacent DVW SWMU 9 area. An evaluation of mean surface soil (0 to 2 feet) concentrations of lead was found to be 825 mg/kg, well below the CAO of 2,240 mg/kg.

Subsurface soils are also limited in impacts at concentrations above the lead CAO. Nine subsurface soil samples in SWMU 23/24, SWMU 27, and the Area South of Middle Creek, and one location west of Middle Creek has exceedances of the lead CAO. The subsurface soil exceedances are also delineated as previously demonstrated in Section 4.0. The mean subsurface soil (greater than 2 ft bgs) concentrations of lead was found to be 2,170 mg/kg, which is also below the CAO of 5,995 mg/kg.

Groundwater at AOI 7 exceeds the groundwater screening criteria (MCLs) in approximately one-third of the wells for facility related constituents however groundwater concentrations not attributable to historic offsite sources are below the conservative trigger concentrations (1,000 to 1) identified in the mixing zone evaluation (Appendix M) indicating that groundwater impacts to surface water from AOI 7 to the Delaware River does not occur. .The conclusions of the SLERA supported that the groundwater within AOI 7 was not adversely impacting surface water quality in Middle Creek.

The SLERA, Appendix N, completed the first 2 steps in the ecological risk assessment process. Even using conservative screening criteria and assumptions the SLERA concluded that there was no significant ecological risk to surface water or sediments and no further ecological risk assessment steps were necessary.

5.4.2 Background – Non-AOI 7 Related Constituents

As noted above, investigations during the RFI have identified the presence of compounds that are believed to originate from off-facility sources based on the record of facility operations and the distribution of the compounds. Pesticides have not been manufactured, stored or used at the MHIC facility in any quantity and Evergreen has no information to indicate that they should be present at the facility as the result of facility related activities. The widespread detection of DDx and BHC compounds in facility soils, groundwater, sediment and surface water is not related to MHIC or former refinery operations.

Arsenic has also been commonly used as a pesticide component, so its coincidence with the DDx and BHC pesticides is consistent with its source from the adjacent property. Figures 5.1 and 5.2 show the distribution of DDx and arsenic in sediments at the facility and adjacent property to the west to demonstrate the relationship between these detections. Historic movement of the materials from the DVM property to AOI 7 media was supported by review of the historic aerials.

5.5 Human Health Risk Evaluation

A streamlined Human Health Risk Assessment (HHRA) was performed to evaluate potential reasonable maximum exposure (RME) risks under current and reasonably anticipated future land use from exposure to soil at AOI 7. The HHRA was performed consistent with USEPA's Risk Assessment Guidance for Superfund guidance documents and used standard default exposure factors where available and appropriate. The following summarizes the approach and results of the HHRA, which is provided in Appendix O. Potential exposure to lead in soil was evaluated using the IUEBK model, as documented in Appendix K and Appendix O.

5.5.1 Approach

AOI 7 has historically been used for petroleum refining-related industrial activity and future uses will be for handling and storage of petroleum products. Upper-bound RME risks were evaluated for potential exposure of routine industrial workers and maintenance/construction workers to soil at AOI 7. The HHRA assumed workers could be exposed to unsaturated soil via incidental ingestion, dermal absorption, inhalation of vapors and inhalation of respirable soil particles even though the majority of AOI 7 is paved and health and safety procedures require use of personal protective equipment during subsurface activities. Activities resulting in potential soil exposure will occur in unsaturated soils (above the water table), therefore the HHRA utilized the unsaturated soil data from the AOI 7 investigation activities.

The potential for significant exposures was evaluated relative to USEPA's risk limits for corrective action, i.e., an excess lifetime cumulative cancer risk management limits of 10^{-4} excess lifetime cumulative cancer risk and a non-cancer hazard index of 1 (USEPA, 1991). The HHRA conservatively calculated risk estimates using maximum detected concentrations for most detected constituents and 95 percent upper confidence limits (95 percent UCLs) on the mean for constituents that contributed most significantly to the cumulative risk estimates.

Risk estimates were calculated for AOI 7, except the area west of Middle Creek. Another set of risk estimates were calculated for the data collected west of Middle Creek, as shown in the figure in Appendix O. The area west of Middle Creek was separated because this area has limited accessibility relative to the remainder of the Site. Figure 5.3 shows the two evaluation areas described above.

5.5.2 Risk Characterization Routine Industrial Workers

Routine industrial workers were conservatively assumed to be exposed to surface soil (0 to 2 ft bgs). The upper-bound RME risk estimates for these exposures are summarized in Table 5.1 and Appendix O provides the risk estimates by chemical and route of exposure.

The soil data collected from MHIC AOI7 do not indicate a potential for significant current or future exposure via direct contact with soil.

The soil data collected from West of Middle Creek do however indicate a potential for significant exposure via direct contact if this soil were routinely contacted. The constituents and concentrations contributing most significantly to the direct contact risk estimates in Table 3 are alpha BHC from MW-557 (120 mg/kg), arsenic from MW-560 (749 mg/kg) and MW-558 (209 mg/kg), and mercury from MW-560 (34.8 mg/kg). As shown on Figure 1, these surface soil locations are from the area west of Middle Creek. This area is at the extreme corner of AOI 7 and is not accessed during routine activities because of access limitation, i.e., limited access, bounded by a steep slope, the boundary fence, and overgrown vegetation.

A more realistic, yet conservative, scenario for routine industrial worker exposure in the area west of Middle Creek would be no more than one visit per week. The RME risk estimates for routine industrial workers are exposed to surface soil in this area up to 50 days/year, and the other exposures factors for routine industrial workers are the same as those presented above. The refined RME risk estimates for these exposures are summarized in Table 5.1 and Appendix O provides the risk estimates by chemical and route of exposure.

The soil data collected from the west of Middle Creek do not indicate a potential for significant current or future exposure via direct contact with soil under the more realistic exposure scenario.

5.5.3 Risk Characterization Maintenance/Construction Workers

Maintenance/construction workers are assumed to be exposed to subsurface soil during construction activities. Maintenance/construction worker exposure to subsurface soil does not occur in the area west of Middle Creek because of the distance from the operating portions of the Site to this area and access limitations. Therefore, risk estimates were not calculated for maintenance/construction worker exposures in this area. The upper-bound RME risk estimates for these exposures at MHIC AOI 7 are summarized in Table 5.1 and Appendix O provides the risk estimates by chemical and route of exposure.

The soil data collected from MHIC AOI7 do not indicate a potential for significant current or future exposure via direct contact with soil during occasional maintenance or construction activities.

5.5.4 Lead

Potential exposure of workers to lead in soil was evaluated separately from the assessment for other constituents because USEPA evaluates the significance of lead exposures using blood lead level as an index of exposure, rather than in terms of cancer risk or non-cancer HQ. As discussed in Appendix K, the lead criterion for routine worker exposure to lead in soil is 2,240 mg/kg and the criterion for maintenance/construction worker exposure to lead is soil is 5,995 mg/kg, which are based on a blood lead modeling approach designed to be protective of potential exposures to soil lead in industrial settings. As USEPA explained in promulgating the regulations at 40 CFR Part 745 (66 FR 1206, January 5, 2001), soil lead screening levels developed based on blood lead modeling should be compared with the arithmetic mean concentration of lead within the area where potential exposures are assumed to occur in order to be consistent with the principles underlying the blood lead modeling approach.

The mean detected lead concentrations for surface and subsurface soil are 825 mg/kg and 2,174 mg/kg, respectively. These are below 2,240 mg/kg and 5,995 mg/kg, respectively. Therefore, no significant exposure of routine workers to soil lead is expected on-site.

5.5.5 HHRA Summary and Conclusions

The results of the HHRA indicate that there are no unacceptable RME cancer risk or non-cancer HI risk estimates for human exposure at or around AOI 7 under current or potential future land uses. The mean detected lead concentrations in soil are below the acceptable levels of lead in soil for workers.

5.6 Ecological Risk Evaluation

GHD completed a screening level ecological risk assessment (SLERA) for AOI 7 based on USEPA guidance (USEPA, 1997, 1998) for assessing ecological risks. AOI 7 is located in the Marcus Industrial Complex (MHIC) on the tidal Delaware River in the Marcus Hook area. The current and future land use is industrial; consequently, no real ecological habitat currently occurs on terrestrial portions of AOI 7 or is anticipated in the future. The terrestrial portion of AOI 7 is comprised almost entirely of impervious surfaces with minimal vegetation and no habitat value. Consequently, exposure pathways from detected compounds in soil to ecological receptors are incomplete. Therefore, concentrations of contaminants in soil were not considered in the SLERA.

The aquatic ecological habitat in AOI 7 is very limited. A small tidal watercourse, Middle Creek, drains AOI 7 and a small area of heavily industrialized land to the northwest. Middle Creek discharges to the Delaware River. The habitat value of Middle Creek is poor. It is an artificial, completely channelized creek without instream habitat variability, habitat structure such as rock dams and logs, or aquatic vegetation. Its banks are stone riprap with minimal vegetation, with the exception of the southwest bank of its lower reaches where there is a naturalizing dredge spoil area and some vegetation. Base flow in Middle Creek is significantly less than tidal flow, with little flowing or stagnant water in the channel during low tides. Even during high tides, Middle Creek constitutes a small area of aquatic habitat of approximately 2.5 acres (approximately 3,000 feet long by 35 feet wide). Since the tides in this area of the Delaware River are about 6 feet, average depth of Middle Creek at high tide is approximately 5 or 6 feet. At low tide, the water depth decreases by approximately 75 percent. Based on the channel construction and water depth, Middle Creek cannot serve as permanent fish habitat, although fish may move in and out of the channel with the tides. The wetted bottom may serve as habitat for aquatic benthos, but these benthos are primarily limited to species that can survive daily periods when sediments are above the water and exposed to the air. Consequently, Middle Creek's biological potential is significantly constrained by its poor habitat and small size.

GHD's assessment of the Creek's very limited ecological potential is corroborated by a previous ecological risk assessment considering releases from the adjacent General Chemical Corporation/Honeywell property (collectively referred to as DVW) to the Delaware River and to upper reaches of Middle Creek (Environ, 2012). In that risk assessment, Environ and USEPA concluded that Middle Creek's ecological potential was so limited that only moderate risk management was necessary to protect ecological receptors. Remedial goals for Middle Creek were about half as stringent as those for the Delaware River.

Notwithstanding the low ecological potential of Middle Creek, exposure pathways between aquatic biota and AOI 7-related compounds in sediments and surface water were considered complete and were assessed in the SLERA. Assessment endpoints chosen for the SLERA were assumed to be the health of surface water and benthic biota. These aquatic biota potentially face direct toxicity from exposure to AOI 7-related compounds in surface water and sediments of Middle Creek. Potential risks to these biota were screened by first comparing maximum detected sample concentrations to conservative ecological screening values (ESV). Compounds whose maximum detected concentrations significantly exceeded ESVs were retained as initial compounds of potential ecological concern (COPEC). For surface water, only DDx (DDT and its breakdown products DDD and DDE) and BHCs (alpha-, beta-, delta-, and gamma-BHCs) were selected as initial COPECs. These pesticides are not likely to be AOI 7-related based on MHIC history, but appear to be due to releases from the DVW property.

Following a similar process, initial COPECs in sediment included the following: total petroleum hydrocarbons (TPH), two volatile organic compounds (VOCs) (chlorobenzene and carbon disulfide), and several non-divalent metals (arsenic, antimony, barium, beryllium, cobalt, selenium, and thallium). Barium, beryllium, and thallium were retained as initial COPECs in sediment because no reliable ESV could be located and therefore these metals were considered qualitatively in the SLERA. Other compounds (divalent metals and polynuclear aromatic hydrocarbons (PAHs) were also detected at concentrations above screening levels in Middle Creek sediment samples. Although the divalent metals and PAHs would have been retained as COPECs using ESVs that do not consider bioavailability in sediments, these compounds were not identified as initial COPECs because their maximum sample concentrations did not exceed sediment ESVs that consider bioavailability.

The SLERA also considered indirect toxicity via bioaccumulated chemicals to semi-aquatic predators. These predators included aerial insectivores (e.g., bats and swallows) consuming adult aquatic insects whose larvae could grow in Middle Creek sediments. The SLERA also considered risks to mink and herons, which could forage on fish from Middle Creek. Using very conservative exposure assumptions and conservative toxicity reference values (TRVs), arsenic, selenium, copper, DDx, and BHCs were retained as initial bioaccumulative COPECs in sediment.

The screening of chemicals and identification of initial COPECs relied on very conservative assumptions. As per USEPA guidance, GHD re-screened these initial COPECs to determine whether they were identified as COPECs due to the conservativeness of the screening methods or whether the COPECs had a reasonable potential to cause ecological effects. Hence, initial surface water COPECs (DDx and BHCs) were rescreened against conservative, but more reliable, predictors of toxicity to aquatic biota. In the re-screening analysis, neither DDx nor BHCs was retained as a final COPEC. Similarly, GHD re-screened the initial sediment COPECs for direct toxicity to benthos using more defensible, but still conservative, ESVs and less conservative exposure point concentrations. None of the initial sediment COPECs were retained as a final COPEC. GHD also re-screened initial bioaccumulative COPECs. All were rejected as final COPECs when realistic area use factors and average concentrations were considered, even though these assessments retained very conservative TRVs and other very conservative assumptions about potential exposures.

At the conclusion of the re-screening analyses there remained three metals (barium, beryllium, and thallium) that had been retained as initial sediment COPECs because reliable ESVs could not be located. GHD dismissed the potential ecological risk of exposure to these metals using a weight of evidence analysis. First, reliable but conservative ESVs exist for toxicity of these metals in surface water, and surface water sample concentrations in Middle Creek were, on average, an order of magnitude or more below than the ESVs. Thus, the biota in the surface water and living at the top of the sediments would not likely be adversely affected by the concentrations of these metals in surface water. Second, contaminant concentrations in the sediment pore water of surficial sediments is expected to remain close to equilibrium with the contaminant concentrations found in surface water because fast currents will occur during the filling and near emptying of Middle Creek during each tidal cycle. Thus, these metals detected in shallow sediment samples likely pose little toxicity to benthic species living deep into the sediments. Third, Middle Creek is a very small area of marginal aquatic habitat. Even if some toxicity did occur from barium, beryllium, and thallium, potential impacts would not be ecologically significant.

Concentrations of DDx, BHC and arsenic are elevated at the mouth of Middle Creek, and decline significantly at upstream locations. This pattern is consistent with these chemicals coming into Middle Creek from the Delaware River or due to historic off-site impacts from the DVW property rather than from AOI 7. Thus, these high concentrations near the mouth are ultimately due to releases of these compounds from the adjacent property. At the two locations nearest the mouth, the concentrations of DDx and arsenic are above the remedial goals developed for Middle Creek by Environ in collaboration and USEPA (2012). As described above, they were not considered in this SLERA to pose ecological risk to Middle Creek because elevated levels only occur in these two locations. Even though they do not cause risk when the entire creek is considered, these far downstream concentrations would, potentially, cause toxicity to benthic invertebrates at these two stations when considered in conjunction with contiguous locations in the Delaware River that have elevated concentrations of DDx and Arsenic, as documented in reports from the DVW property. Thus, the finding of no risk for the entirety of Middle Creek for arsenic, DDx, and BHCs does not negate previously derived remedial goals for these compounds by Environ (2012) for the adjacent property and the potential need for remedial action at these locations if considered as part of a remedial action for the Delaware River.

In summary, re-screening of initial COPECs suggests minimal potential for ecologically significant toxicity from AOI 7-related contaminants. Low potential for ecological risk is also indicated, independently, by the very small area and poor habitat value of Middle Creek. Consequently, the potential for ecological risks can be dismissed based on available information. No further ERA activities are warranted.

6. Summary and Conclusions

6.1 Summary of RFI

The RFI was conducted in AOI 7 to address corrective action requirements under RCRA. The RFI was designed to characterize soil, groundwater, surface water and sediments in accordance with the provisions of the CAF agreement with EPA for MHIC. The RFI performed in AOI 7 investigated six areas, including two SWMU areas (SWMU 23/24 Old Sludge Basin/Old Decant Basin and SWMU 27 Phillips Island), and four non-SWMU areas (Middle Creek Area, Area South of Middle Creek, Area West of Middle Creek and, the 17 Plant Area). Soil borings and additional monitoring wells were installed to complete the investigations. Sampling included 117 soil samples from 77 locations, two rounds of groundwater samples from 44 monitoring wells, and one seep sample collected from the east side of the downstream segment of Middle Creek. Three rounds of surface water samples and two rounds of sediment samples were collected from 10 locations in Middle Creek.

The following sections summarize these results.

6.1.1 Soil

6.1.1.1 SWMU 23/24 – Old Sludge/Decant Basin

- Lead exceeded the CAO at two surface soil locations (AOI7-BH-16-010 and AOI7-BH-16-011).
- Lead exceeded the CAO at two subsurface locations - (AOI7-BH-15-007 at 11 to 12 ft bgs and AOI7-BH-15-008 at 8 to 10 ft bgs)

6.1.1.2 SWMU 27 – Phillips Island

- Lead exceeded the CAO at one surface soil location (MW-527 at 1 to 3 ft. bgs).

6.1.1.3 Middle Creek Area

- No results in the surface soils at the Middle Creek Area exceeded the lead CAO.
- Lead exceeded the CAO at one subsurface location - (MW-539 at 6.5 to 8 ft. bgs).

6.1.1.4 Area South of Middle Creek

- No CAO exceedances were observed in soils from the surface soils in the Area South of Middle Creek.
- Lead exceeded the CAO in one sub surface location (MW-562 at 8 to 9 ft. bgs).

6.1.1.5 Soils West of Middle Creek

- Lead exceeded the CAO at one surface soil location (MW-560).
- Lead exceeded the CAO at one subsurface location (MW-560 at 2 to 5 ft bgs).

6.1.1.6 17 Plant Area

- None of the surface or subsurface soil analytical results in the 17 Plant Area exceeded the lead CAOs.

6.1.1.7 AOI 7 Soils HHRA

- The HHRA assessed direct contact of workers performing routine or maintenance activities in AOI 7 to soil. The HHRA also evaluated exposures to maintenance/construction workers.
- The results of the HHRA indicate that there are no unacceptable RME cancer risk or non-cancer HI estimates for human exposure at or around AOI 7 under current or potential future land uses.

6.1.2 Groundwater

Groundwater concentrations in all monitoring wells were detected below the groundwater CAOs and the conservative trigger levels (1,000 to 1) with the exception of arsenic and pesticides in monitoring wells influenced by historic deposition from off-site impacts.

6.1.3 Surface Water and Sediment

A SLERA was completed to evaluate surface water and sediment conditions in Middle Creek. The SLERA concluded that there was minimal potential for ecologically significant toxicity from AOI 7-related contaminants. Low potential for ecological risk was also indicated, independently, by the very small area and poor habitat value of Middle Creek. Consequently, the potential for ecological risks was dismissed in the SLERA and no further ERA activities are warranted.

6.2 Conclusions

Soil and groundwater at AOI 7 have been impacted by both potentially facility-related and historic deposition of non-facility related constituents of concern. Soil concentrations for facility related constituents meet lead CAOs for average conditions and individual locations of exceedances are well delineated by adjacent data. Other constituents detected in soils at AOI 7 were found to pose no unacceptable RME cancer risk or non-cancer HI estimates for human exposure under current or potential future land uses.

Groundwater discharging to the Delaware River is of sufficient quality to attain DRBC fish ingestion criteria in the Delaware River, with the exception of pesticides and arsenic at limited locations, all of which were impacted by historical off-site deposition.

The SLERA identified no unacceptable risks to ecological receptors from Middle Creek sediment and surface water. Only samples from the most downstream stations (SED-001 and SED-002) have concentrations of DDx or arsenic exceeding the values developed by Environ on behalf of

Honeywell for its sediment corrective actions in Middle Creek and these areas were impacted by historical off-site deposition.

7. Recommendations

A CMS is recommended to:

- Further evaluate the soils and groundwater exceeding the CAOs, with the exception of the COCs attributed to historic off-site deposition.
- Develop a groundwater monitoring program to assess ongoing groundwater quality in relation to the CAOs developed based on the groundwater to surface water mixing value for a conservative evaluation of surface water quality standards (DRBC criteria as described in 2.5.2.5.4) thereby establishing the groundwater CAOs.
- Develop a decision making process for corrective action, if appropriate, to protect surface water quality.

Assuming corrective action for sediments in Middle Creek for arsenic and pesticides will be addressed by the proposed corrective action program for the DVW, no further assessment in AOI 7 is warranted.

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